LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
SITE 7A
FEASIBILITY DESIGN REPORT

March, 1986

Prepared For:

Alberta Environment
Planning Division

Prepared By:
W-E-R Engineering Ltd.
in association with
Thurber Consultants Ltd.

water
environment resources

March 26, 1986 File: 1006.02.101

Alberta Environment
Planning Division
200 - 5 Avenue South
Lethbridge, Alberta
T1J 4C7

Attention: Mr. Sandy Larsen, P.Eng.
Assistant Oldman River Basin Planner

Re: Little Bow River Basin
Storage Investigation, Site 7A
Feasibility Design Report

Dear Mr. Larsen:

W-E-R Engineering Ltd. is pleased to submit herewith its final report entitled "Little Bow River Basin Storage Site Investigation, Site 7A - Feasibility Design Report", March, 1986.

The investigation was conducted in association with Thurber Consultants Ltd. who were responsible for the geotechnical assessment.

This report outlines the results of feasibility design studies undertaken for reservoir storage alternatives of 50 and 70 thousand acre-feet at Little Bow Site 7A.

Our firm appreciates the opportunity to be involved in the development of storage in this water-short area of Southern Alberta. It has been a most challenging assignment.

We would be pleased to meet with you at your convenience to discuss the results of this investigation.

Yours very truly,

W-E-R ENGINEERING LTD.

J. M. Wise, P.Eng.
Vice-President

JMW:pc

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
GEOLOGISTS and GEOPHYSICISTS
OF ALBERTA
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SYNOPSIS

Conceptual design studies conducted by W-E-R Engineering Ltd. in the summer of 1985 (Reference 1) examined three storage sites below the confluence of the Little Bow River and Mosquito Creek, namely, Little Bow Sites 7A, 7B and 7B-1. Based on that report's recommendation, Site 7B-1 was retained for a feasibility level investigation (Reference 2).

In November 1985, the studies were expanded, at the request of the local advisory committee, to allow for the investigation of Little Bow Site 7A at the feasibility level. The study was to include a limited test hole program adequate to confirm foundation conditions and reservoir integrity.

This report describes the engineering studies carried out by W-E-R to determine the technical feasibility of two storage levels at Little Bow Site 7A and provides hydrology and water supply, geotechnical, feasibility design and reservoir cost investigations for the storage alternatives under consideration.

The total estimated costs for the two reservoir storage alternatives are as follows:

Storage Capacity	Project Cost	Cost per Ac.Ft.* of Basin Yield
50,000 ac.ft.	$21,197,000	$279
70,000 ac.ft.	$25,162,000	$307

The investigation identifies seepage control as a major problem at Site 7A due to significant depths of relatively pervious soils at the site. Consequently, Site 7A has not been recommended for implementation.

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*Based on new 60 percent guideline with 60 cfs (Squaw Coulee) and 300 cfs (Little Bow) diversion capacities. Does not include cost of increasing diversion capability.

TABLE OF CONTENTS

Page No.

1.0 INTRODUCTION 1

2.0 HYDROLOGIC ASSESSMENT 3

2.1 Water Supply 3
2.2 Flood Flows 5

3.0 GEOLOGICAL/GEOTECHNICAL 6

3.1 Field Work 6
3.2 Site Geology 6
3.3 Reservoir Shoreline Stability 7
3.4 Reservoir Watertightness 7
3.5 Embankment Siting 8
3.6 Embankment Cross-section 8
3.7 Site Preparation 9
3.8 Seepage Control 9
3.9 Spillway 10
3.10 Low Level Conduits 10
3.11 Concrete 11
3.12 Additional Geotechnical Investigations 11

4.0 DESIGN STUDIES

4.1 General 12
4.2 Project Requirements 12
4.3 General Layout 13
4.4 Spillways 13
4.5 Irrigation Conduits 14
4.6 Construction Cost Estimates 14
4.7 Project Implementation 14

5.0 RESERVOIR COSTS 16

5.1 Basis of Costing 16
5.2 Little Bow Site 7A - 67 100 dam^3 16
5.3 Little Bow Site 7A - 86 300 dam^3 18

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions 19
6.2 Recommendations 20

LIST OF REFERENCES 21

LIST OF FIGURES

Figure No.	
1	Location Plan
2	Basin Yield Versus Diversion Capacity Curves
3	General Layout - 61 700 dam^3 (50,000 ac.ft.) Storage Alternative
4	General Layout - 86 300 dam^3 (70,000 ac.ft.) Storage Alternative

LIST OF TABLES

Table No.	
1	Project Data and Cost Estimate Summary - 61 700 dam^3 (50,000 ac.ft.) Storage Alternative
2	Project Data and Cost Estimate Summary - 86 300 dam^3 (70,000 ac.ft.) Storage Alternative

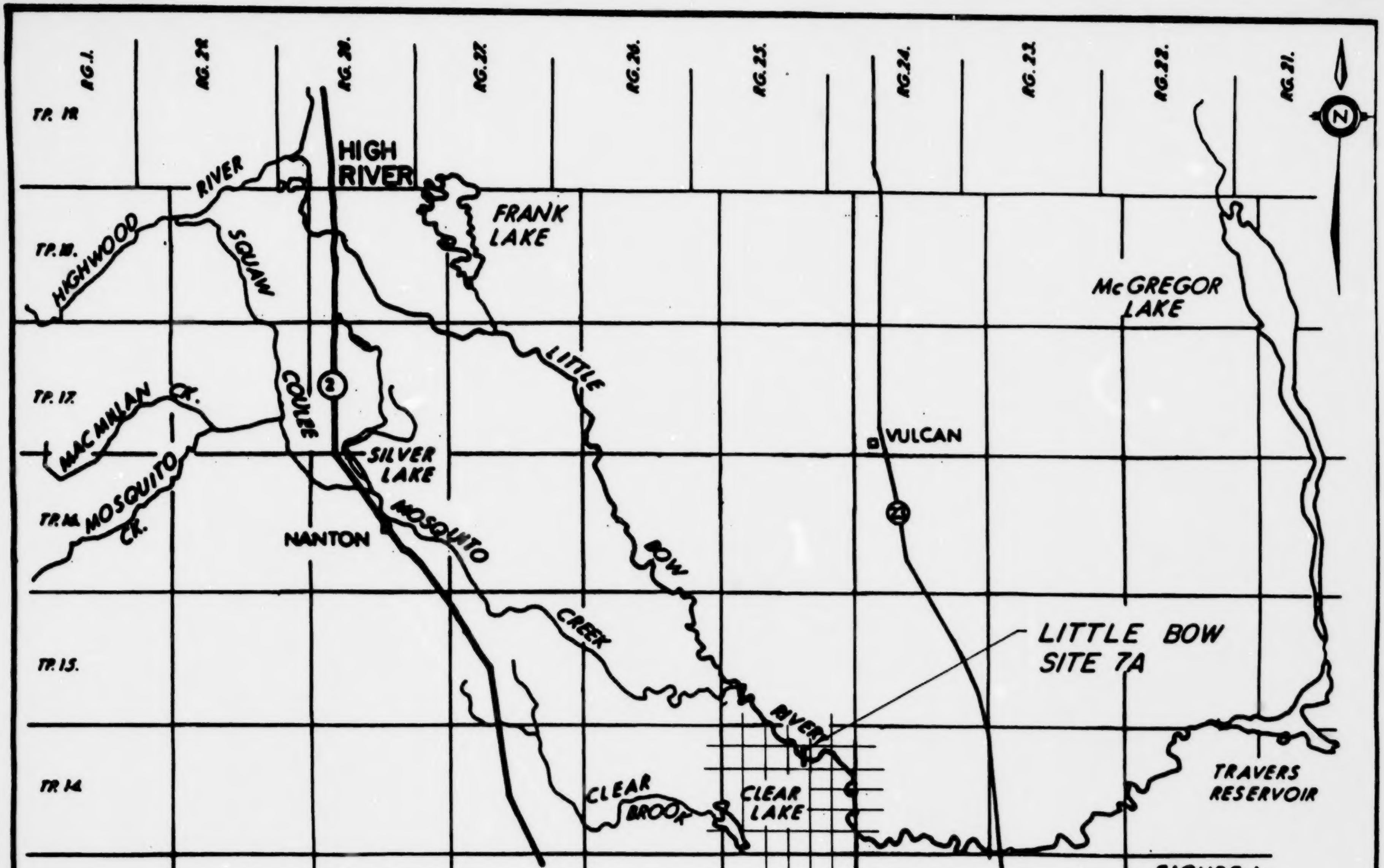
LIST OF APPENDICES

A - WATER SUPPLY AND HYDROLOGY STUDY

B - GEOLOGICAL/GEOTECHNICAL EVALUATION

C - DETAILED SUMMARY OF DESIGN STUDIES AND COST ESTIMATES

D - RESERVOIR COSTS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HIGHWOOD RIVER
SQUAW COULEE
MACMILLAN CR.
MOSQUITO CR.
2
SILVER LAKE
NANTON
MOSQUITO CREEK
LITTLE BOW RIVER
VULCAN
23
LITTLE BOW SITE 7A
CLEAR BROOK
CLEAR LAKE
TRAVERS RESERVOIR

FIGURE. I.

LITTLE BOW RIVER BASIN LOCATION PLAN

1.0 INTRODUCTION

Irrigation water shortages within the Little Bow River Basin in recent years which have resulted from a combination of drought and a high water demand have clearly demonstrated the need for reservoir construction within the basin.

Alberta Environment's on-going Phase II studies which constitute a water management plan for the basin have included a requirement to investigate potential storage reservoir sites. Accordingly, W-E-R Engineering Ltd. has been retained to conduct a number of damsite investigations for the development of storage within the Little Bow Basin.

Recent studies by W-E-R Engineering have addressed potential storage reservoirs immediately below the confluence of the Little Bow River and Mosquito Creek. A conceptual study completed in August, 1985 (Reference 1) examined three confluence sites - Little Bow Sites 7A, 7B and 7B-1. On the basis of that study Site 7B-1 was considered to be the preferred site. A subsequent investigation evaluated Site 7B-1 at the feasibility level (Reference 2).

Late in 1985, the studies were expanded, at the request of the local advisory committee, to allow for a feasibility assessment of Site 7A (see Figure 1). The new investigation was to include a test hole program to adequately confirm foundation conditions and reservoir integrity for that site.

The present report describes the results of this Little Bow Site 7A feasibility level study, considering the development of two alternative storage levels - 61 700 and 86 300 dam^3 (50,000 and 70,000 ac.ft.).

Confluence site investigations have also incorporated the new 60 percent (of Highwood River flows) guideline, with diversion rates for Squaw Coulee set at the present system capacity of 1.70 m^3/s (60 cfs), and capacities at the Little Bow Canal ranging from 2.83 m^3/s (100 cfs) to 14.2 m^3/s (500 cfs).

This report compares the two reservoir alternatives at Site 7A on the basis of water supply capability, geotechnical considerations, structure layout and design, reservoir damages, land acquisition, and costs of implementation. The study results have also been summarized in the form of design layouts, pertinent data, and cost summaries at the end of this main report in Tables 1 and 2 and Figures 3 and 4.

Little Bow Sites 7A and 7B-1 are only about 6 km apart and the difference between their drainage areas is considered to be insignificant. For that reason the feasibility level water supply and hydrology investigations previously carried out by Nanuk Engineering and Development for Site 7B-1 (Reference 2) have also been utilized for the current Site 7A study.

Details of each of the study components are included in the following appendices:

- o Appendix A - Water Supply and Hydrology Study
- o Appendix B - Geological/Geotechnical Evaluation
- o Appendix C - Detailed Summary of Design Studies and Cost Estimates
- o Appendix D - Reservoir Costs

On the basis of the feasibility design investigations, recommendations concerning Site 7A are presented at the end of the main report.

2.0 HYDROLOGIC ASSESSMENT

The water supply and flood flow assessments presented in this section for Site 7A are the same as those provided for Site 7B-1 (Reference 2). Since the two sites are only about 6 km apart they are considered to be essentially equal with respect to hydrology, and no allowance has been made for the minimal difference in drainage area between them.

The results of this hydrologic assessment, the details of which are presented in Appendix A, were used to support selection of reservoir storage capacity and spillway design.

2.1 Water Supply

The water supply capability of site 7A was evaluated by determining the total basin yield provided by two levels of storage - 61 700 and 86 300 dam^3 (50,000 and 70,000 ac.ft.) Basin yield is the total water available to meet all requirements, but primarily for irrigation use, and is not synonymous with reservoir release. The capacity of the Little Bow Canal was also varied from 2.83 (100 cfs) to 14.2 m^3/s (500 cfs) in steps of 2.83 m^3/s (100 cfs) to assess the effect of increased diversion capability from the Highwood River.

a) Data Base

Water available from the Highwood River for diversion to the Little Bow Basin was based on the following operational guideline;

- o maximum volume diverted cannot exceed 60% of the daily flow in the Highwood at High River,

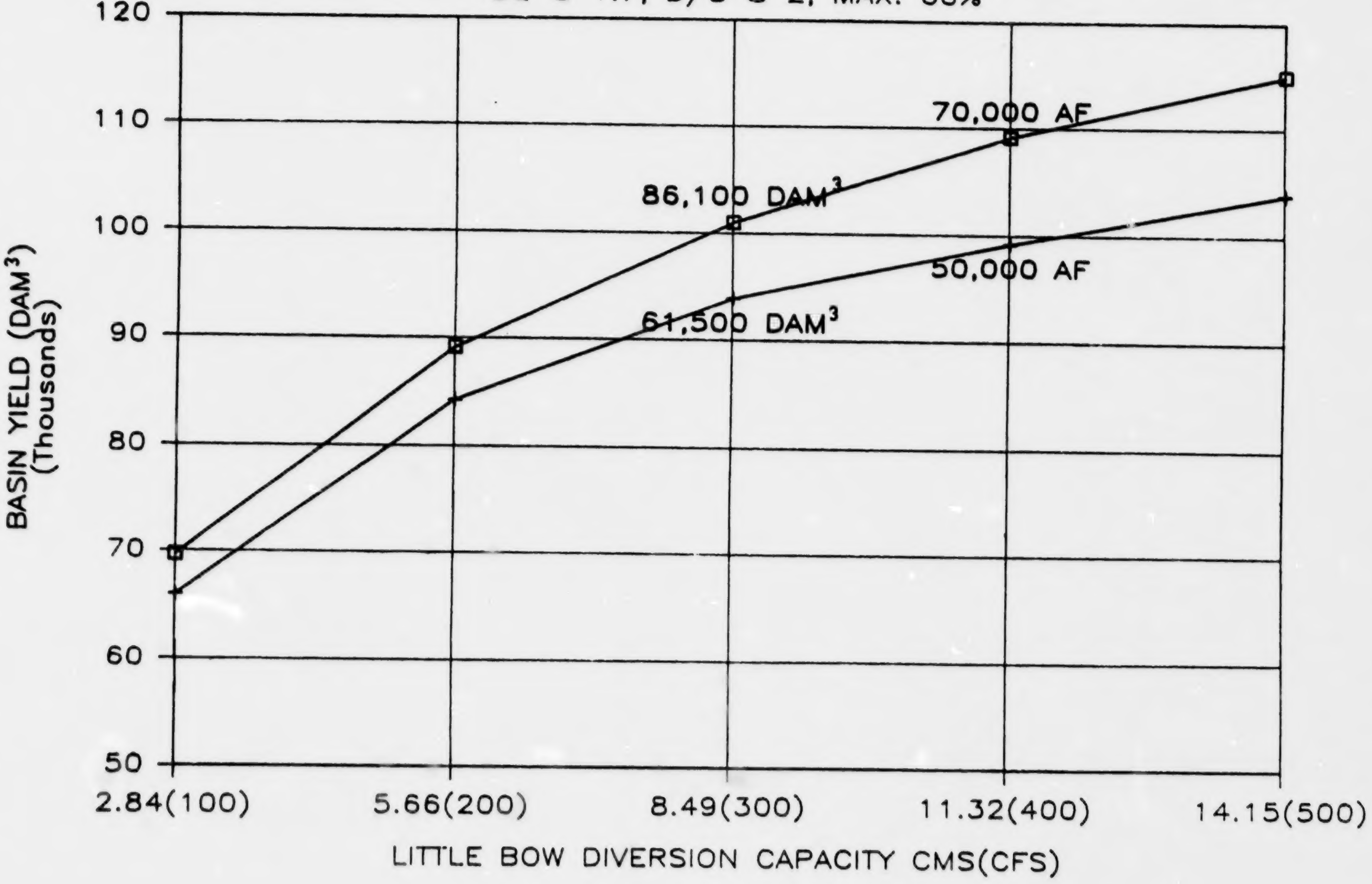
- a residual flow of 1.98 m^3/s (70 cfs) must remain in the Highwood downstream of the headgate for the Little Bow Canal.

The Squaw Coulee diversion capacity was set at 1.70 m^3/s (60 cfs) for all evaluations. The operating season for the two diversion canals was assumed to be April 15 to October 15.

b) Methodology and Results

The period 1916 to 1941 was selected for the water supply study since it included the most critical drought period on record. Water in excess of the total basin requirement, in a particular month, was stored in the reservoir. Stored water at the end of the irrigation season was carried forward into the next year. The basin requirement was constant throughout one simulation. The water requirement was incremented, in subsequent simulations, until a deficit occurred. This requirement then became the total basin yield for the simulated reservoir storage. Diversion capacity was then changed and a new basin yield determined by iteration. The water balance model considered all inflows (diversions and natural), evaporation, but not channel losses.

Based on these studies, a capacity for the Little Bow Canal can be selected and an appreciation of the effectiveness of increasing storage can be gained. Figure 2 illustrates the effect of increasing diversion canal capacity and changing the storage capacity of the reservoir. The following observations can be made from Figure 2:



LITTLE BOW SITE 7A

SQ @ 1.7, D/S @ 2, MAX. 60%

W-E-R ENGINEERING LTD.

NANUK Engineering
Figure 2

1. A canal capacity between 5.67 (200 cfs) and 8.50 (300 cfs) m^3/s produces appreciable increases in basin yield over the 2.83 m^3/s (100 cfs) capacity. Beyond 8.50 m^3/s (300 cfs), yield increases are relatively small.

2. The 61 500 dam^3 (50,000 ac.ft.) reservoir produces a yield similar to the 86 100 dam^3 (70,000 ac.ft.)reservoir at 8.50 m^3/s (300 cfs) diversion capacity for both. The 24 600 dam^3 (20,000 ac.ft.) increase in storage produces a 7 400 dam^3 (6,000 ac.ft.) change in yield.

2.2 Flood Flows

Flood frequency analyses were carried out for use in the design of spillways and construction diversion works for each site. The probable maximum flood (PMF) was determined using Saskatchewan-Nelson Basin Board data. The 1 in 100 year and 1 in 25 year floods were determined using frequency analysis from recorded maximum daily flows of the Little Bow River at Carmangay. A complete description of the methodology can be found in Appendix A.

The flood flows for preliminary design are:

PMF - 570 to 700 m^3/s (20,000 to 25,000 cfs) (maximum mean daily flow)

1:25 year - 85 m^3/s (3,000 cfs) (peak instantaneous)

1:100 year - 150 m^3/s (5,200 cfs) (peak instantaneous)

3.0 GEOLOGICAL/GEOTECHNICAL

This section presents a preliminary geotechnical evaluation of a damsite located on the Little Bow River about 24 km southeast of Parkland, Alberta. The site has been designated as Site 7A. Two different reservoir storage capacities are being considered at this site, and therefore, two different embankment heights have been examined.

3.1 Field Work

A drilling program consisting of seven test holes drilled along the proposed dam centreline was carried out during January, 1986. The drilling program included sampling of the overburden soils and continuous coring of bedrock.

3.2 Site Geology

The stratigraphy at the proposed damsite is relatively complex. At this location, the Little Bow River is about 30 m below the uplands elevation. A high level terrace, about 15 to 20 m above river level is present on the left (north) bank of the river.

Fine to medium sand and silt of glaciolacustrine origin occurs to depths of 18 to 22 m at the abutments on the upland areas. This is underlain by clay till and bedrock on the right (south) side. A stratum of alluvial sand and gravel was found between the glaciolacustrine and clay till strata on the left side.

The high level terrace is mantled with about 3 m of soft to firm silt and clay, overlying alluvial gravel, clay till and bedrock. In the valley bottom sand or gravel alluvium overlies bedrock.

Depth to bedrock in the test holes ranged from about 5 m in the valley bottom to as much as 38 m in the upland area at the left abutment. The bedrock stratigraphy was comprised of siltstone and claystone overlying sandstone. Evidence of glacial ice-thrusting of bedrock was encountered at Site 7A with bedrock found overlying till at two test holes. It is possible that much of the claystone and siltstone found above sandstone may be present at this site as a result of ice-thrusting.

3.3 Reservoir Shoreline Stability

Three deep seated landslides have been noted along the valley walls 10 to 15 km upstream from the dam embankment, one of which falls within the limits of the proposed reservoir. Detailed geotechnical investigations will be required to assess the effects of the stability of the affected landslide. This work should include an assessment of possible wave generation by landslide activity.

No significant concerns with respect to reservoir shoreline stability were identified in any other locations within the reservoir. Deep seated landslides are possible in some areas, however, the frequency of occurrence of such landslides is expected to be very low. Shallow instability can be expected along the reservoir shorelines due to wave erosion. The beaches are expected to be self stabilizing over 20 to 30 years.

3.4 Reservoir Watertightness

Lateral seepage from the reservoir is not a major concern at this time. A detailed hydrogeological investigation will be required during detailed design in order to confirm this assessment.

3.5 Embankment Siting

Major geotechnical concerns affecting the design and construction of the dam at this location include the presence of pervious strata, the significant depth to bedrock, the occurrence of ice-thrusted bedrock and groundwater under artesian pressure.

3.6 Embankment Cross-Section

A zoned earthfill embankment has been recommended for both dam embankment heights. A suitable source of clay borrow for use in dam construction has not been identified, however, the configuration recommended here assumes that a source can be located on the uplands within a reasonable haul distance. If a suitable source of clay cannot be identified, then the embankment cross-section proposed here will have to be modified to use larger quantities of locally available materials.

It is recommended that the downstream slopes be constructed at an average 3 horizontal to 1 vertical, while the upstream slopes would be constructed at an average 4 horizontal to 1 vertical. It is anticipated that the slopes can be bermed, with overall average slope angles as given above, in order to reduce the quantity of fill required for the embankments. A decision in this regard will depend on the results of material balance studies, laboratory test results and stability analyses which should be undertaken during detailed design.

The failure mechanism of the three landslides located upstream from the proposed dam site should be established. The results of that work will have an impact on the soil parameters used for the design of the dam embankment. It is possible that the embankment slideslopes may have to be flattened significantly from those recommended here, if the landslides are the result of the presence of weak layers within the bedrock. The presence of ice-thrusted bedrock and its significance should also be examined in more detail prior to final design.

3.7 Site Preparation

Site preparation for dam construction will require removal of organic materials and zones of soft soil. This will involve a requirement to remove up to 3 m of material from the high level terrace on the left bank. Seepage into this excavation is a concern due to the presence of groundwater under artesian pressure in the area.

3.8 Seepage Control

The control of seepage is a major concern at Site 7A. Due to the presence of significant depths of relatively pervious soils in the abutment areas and under the high level terrace, the seepage control measures required will include a positive cutoff, an upstream impervious clay blanket and a downstream reverse filter blanket, together with a conventional toe drain below the embankment. Relief wells will also be required at the downstream toe.

The purpose of the seepage control measures is primarily to maintain structural integrity of the dam, and to reduce seepage quantities. It should be noted, however, that the proposed seepage control measures will not eliminate seepage in the area of the dam.

In view of the significant concerns associated with the control of seepage at Site 7A, it is recommended that a greater than normal contingency be allowed in the cost estimate for this aspect of the dam construction.

3.9 Spillway

A single spillway, excavated around the right dam abutment is being proposed at this site. The depth of excavation for the spillway will depend on the maximum reservoir operating level ultimately selected. The excavation will be carried out primarily through glaciolacustrine sands and silts. No information on the depth to groundwater within the sands and silts is available in the vicinity of the proposed excavation. Significant construction difficulties will be encountered if the base of the excavation must be taken below the groundwater table.

Provided the groundwater table is below the base of the spillway, permanent slopes in the silty sands should be cut at 3 horizontal to 1 vertical. If the base of the spillway is below the groundwater table, sideslopes will have to be flattened and permanent drainage will have to be installed to ensure the stability of the sideslopes.

The spillway approach channel will be excavated through silty sand. It should therefore be lined with an impervious clay blanket to minimize seepage from the channel.

3.10 Low Level Conduit

The low level conduit should be founded either on bedrock, or on compacted silty clay fill which extends below the conduit down to the bedrock. The conduit should therefore be located where the depth to bedrock is a minimum.

3.11 Concrete

Sources for concrete aggregate have not been confirmed. It is anticipated that suitable aggregate (which will have to be crushed, screened and washed) can be located in the alluvial sediments upstream from the dam site. It is recommended that Type 50 sulphate resistant cement be used for all concrete in contact with soil at this site.

3.12 Additional Geotechnical Investigations

Prior to final design, a comprehensive drilling program will be required in order to further delineate subsurface conditions at the proposed site. Other geotechnical studies, as detailed in the report, will also be required.

4.0 DESIGN STUDIES

4.1 General

Feasibility design studies were carried out for each of the two reservoir alternatives under consideration at Little Bow Site 7A. These investigations covered structure layouts, hydraulic and structural designs and costing for the main dam and appurtenant works. Details of the design studies are presented in Appendix C.

The feasibility studies utilized the current water supply and hydrology and geotechnical evaluation in support of designs for the main dam, spillway and conduit structures.

Topographic mapping produced for previous studies (References 1 and 2) at a scale of 1:10,000 with 2 metre contour intervals was again utilized to generate area capacity curves and determine damage costs for the reservoir alternatives.

4.2 Project Requirements

Basic project requirements of the present study included: a) the evaluation of two alternative reservoir sizes for Site 7A - 61 700 and 86 300 dam^3 (50,000 and 70,000 ac.ft.), b) controlling flood events set at 1:100 for the spillway structure design flood and 0.5 PMF for the project design flood with appropriate freeboard allowances for wind setup, wave runup, gate operation failure and frost action, and c) downstream irrigation requirements established at 8.5 m^3/s (300 cfs) at minimum reservoir level.

4.3 General Layout

General arrangements of the dam and appurtenant structures are shown in Figures 3 and 4 with pertinent data provided in Tables 1 and 2.

For the two reservoir alternatives under consideration, the dam centreline location is the same as that used in the conceptual design study (Reference 1).

Structure layouts have been selected to take advantage of the topographic and geological conditions at the site.

Embankment designs are based on the geotechnical investigations presented in this report. Special measures are required for seepage control, including a deep cutoff, removal of soft soils, upstream and downstream blankets and relief wells.

4.4 Spillways

Reinforced concrete, gated chute spillways with hydraulic jump stilling basins are proposed for handling floods in each alternative. The spillway structures would be equipped with automatically operated, motorized radial gates.

Spillway crest length and gate height combinations have been optimized to provide the most cost effective arrangement. Chute structures have been designed with a flared configuration to ensure that flow energy is adequately dissipated.

The selection of spillway structural components (sizing of wall and slab thicknesses) has been made on the basis of existing structures of a similar type. Extra deep cutoffs, key walls, and drainage systems have been incorporated into the design to control foundation seepage. Conventional articulation and jointing have been provided to accommodate movements.

The spillway approach channels would be excavated in sand and require a clay liner to minimize seepage.

4.5 Irrigation Conduits

Irrigation conduits are essentially low level outlet structures designed to meet the downstream irrigation demand. The outlet conduits, as proposed, consist of precast concrete pipelines with reinforced concrete inlet, gatewell and outlet structures. The gatewells would be two-celled structures equipped with both service and auxiliary (emergency) gates for the control of irrigation flows. The conduits will also serve as temporary diversion works during the construction stage of the project.

4.6 Construction Cost Estimates

Cost estimates for the main dam and appurtenant structures, including allowances for contingencies and engineering, are provided in Tables 1 and 2. Unit prices used in preparing these estimates are based on recent bid prices for similar projects in Southern Alberta. Allowances have been made for difficult excavation conditions due to anticipated high water tables at this site. Overhaul for excavation has also been allowed for to reflect the shortage of impervious borrow in the immediate vicinity of the dam.

4.7 Project Implementation

It is estimated that final designs and the preparation of tender documents for the project can be completed in about one year. This would include the 5-6 months required to complete the geotechnical investigations outlined in Section 3. Construction of either of the two reservoir alternatives under consideration will require two seasons. Ideally, designs could be carried out over winter with tenders called the following spring. Winter construction of structural components would also be feasible.

5.0 RESERVOIR COSTS

An estimate of the costs of land acquisition and reservoir damages has been prepared for each of the two reservoir capacities, as summarized in the following sections of this report. A feature of the reservoir costs as compared with Site 7B-1 (Reference 2) is the retention of Highway 529 as an in-situ causeway across the reservoir. Details of the reservoir costs are included in Appendix D.

5.1 Basis of Costing

Reservoir land costs are based on the total land control requirements taken to the crest of the dam and include an allowance for severance and acquisition.

Reservoir damages include the cost of roads and bridges, power lines, gas pipeline, water intake system, AGT lines and relocation of farm buildings.

Total reservoir costs for each site are provided in Tables 1 and 2.

5.2 Little Bow Site 7A - 67 100 dam^3 (50,000 ac.ft.)

a) Land Acquisition

A total of 1,005 ha of land to the top-of-dam elevation (961.6 m) are affected, 315 ha of which are cultivated.

b) Roads and Bridges

The costs of retaining the existing alignment of Secondary Highway 529 and a crossing in the SE 26-15-26-W4 (Allston Crossing) has been included in the estimate of reservoir costs.

c) Farm Buildings

Three farmsteads and the Little Bow River Hutterite Colony will require relocation.

d) Utilities

A three-phase power line on double wooden poles crosses the Little Bow River along the east boundary of Section 31-14-25. Special long span towers are proposed at the top of the valley.

A small single phase power line which crosses near the upper end of the reservoir in the S 1/2 26-15-26 would have to be relocated.

No pipelines were found to be affected by the reservoir with the exception of natural gas service lines to farm buildings which are to be relocated.

The Town of Vulcan water intake and pumphouse in the NE 35-15-26-W4 would have to be moved northeast to above top-of-dam elevation. This would require removal of some existing supply line and construction of a new intake line and pumphouse.

One short section of AGT telephone line in the SW 18-15-25 would have to be relocated.

5.3 Little Bow Site 7A - 86 300 dam^3 (70,000 ac.ft.)

a) Land Acquisition

A total of 1,235 ha of land to the top-of-dam elevation (964.6 m) are affected, 324 ha of which are cultivated as hayland or crop land.

b) Roads and Bridges

The estimated reservoir damages include the costs of providing two reservoir crossings as per Section 5.2 (b).

c) Farm Buildings

Three farmsteads and the Little Bow River Hutterite Colony will require relocation.

d) Utilities

Utility relocations remain as outlined in Sections 5.2 (d) of this report.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. Although it is technically feasible to construct a storage reservoir at Little Bow Site 7A for either of the two capacities under consideration, seepage is a major concern at Site 7A due to the presence of significant depths of relatively pervious soils in the abutments and under the high level terrace. Special measures will be needed to control seepage including a deep cut-off trench, upstream and downstream blankets and relief wells.

2. Construction problems at this site will include overhaul for embankment materials, high groundwater tables and the removal of large quantities of soft clay.

3. The spillway will require an upstream blanket, deep cut-offs and special drainage provisions to alleviate the seepage problems.

4. The total estimated costs for the two storage alternatives are as follows:

Site 7A Storage dam^3 (ac.ft.)	Project Cost	Cost/dam^3 (ac.ft.)* of Yield
61 700 (50,000)	$21,197,000	$226 (279)
86 300 (70,000)	$25,162,000	$249 (307)

*Based on new guidelines and existing diversion capacities.

5. The total project costs for the 61 700 dam^3 (50,000 ac.ft.) storage level has increased about 85 percent as compared with the conceptual study. The higher construction costs are attributed to the adverse seepage and construction conditions at this site as outlined in Conclusion Nos. 1 - 3

6.2 Recommendations

Based on the feasibility design studies conducted as well as a comparison with the feasiblity study carried out for Site 7B-1 (Reference 2), it is recommended that this site not be considered for implementation.

LIST OF REFERENCES

1. "Little Bow River Basin Storage Site Investigation, Confluence Sites, Conceptual Design Report - August 1985" by W-E-R Engineering Ltd.

2. "Little Bow River Basin Storage Site Investigation, Confluence Site (7B-1), Feasibility Design Report - September, 1985" by W-E-R Engineering Ltd.

TABLE 1
Pertinent Data and Cost Summary
Little Bow Site 7A
61 700 dam^3 (50,000 ac.ft.) Storage Alternative

Reservoir

Full Supply Level (FSL)	958.6 m
Total Storage at FSL	61 700 dam^3
Flooded Area at FSL	770 ha
Project Design Flood - 0.5 PMF (inflow)	322.8 m^3/s
Spillway Design Flood - 1:100 (inflow)	147.3 m^3/s
Freeboard at FSL	3.0 m

Embankment

Top of Dam Elevation	961.6 m
Maximum Height	24.6 m
Volume of Fill	1 102 000 m^3

Spillway

Crest Elevation	956.5 m
Radial Gates	3 @ 3.5 m (W) x 2.1 m (H)
Basin Elevation	935.4 m
Design Discharge (1:100 routed outflow)	84.6 m^3/s
Probable Maximum Discharge (0.5 PMF routed outflow)	239.2 m^3/s

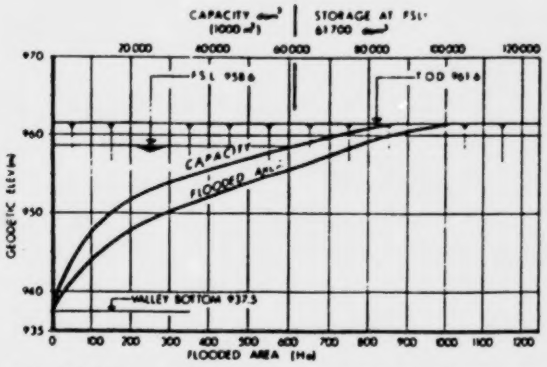
Irrigation Supply Conduit

Conduit Diameter	1.5 m
Irrigation Supply Capacity Requirement	8.5 m^3/s
Gate Size	2 @ 2 m x 2 m
Intake Crest Elevation	942.5 m
Minimum Reservoir Elevation to Pass Irrigation Requirement	943.2 m

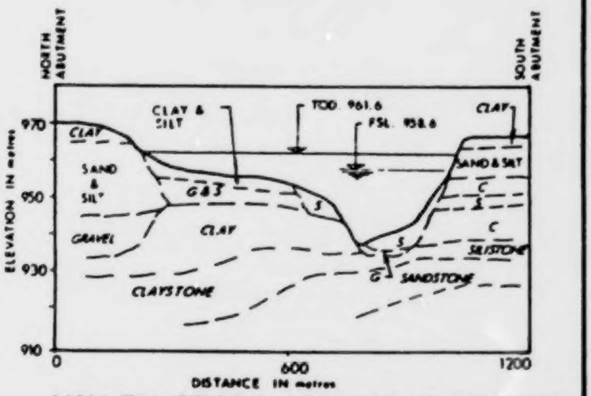
Cost Estimate Summary

Mobilization	$ 100,000
Care of Water	242,000
Embankment	6,769,000
Spillway	2,045,000
Irrigation Supply Conduit	669,000
Subtotal	$ 9,825,000
Contingencies (25%)	2,456,000
Subtotal	12,281,000
Engineering (15%)	1,842,000
Reservoir Costs	7,074,000
Total Project Cost	$21,197,000

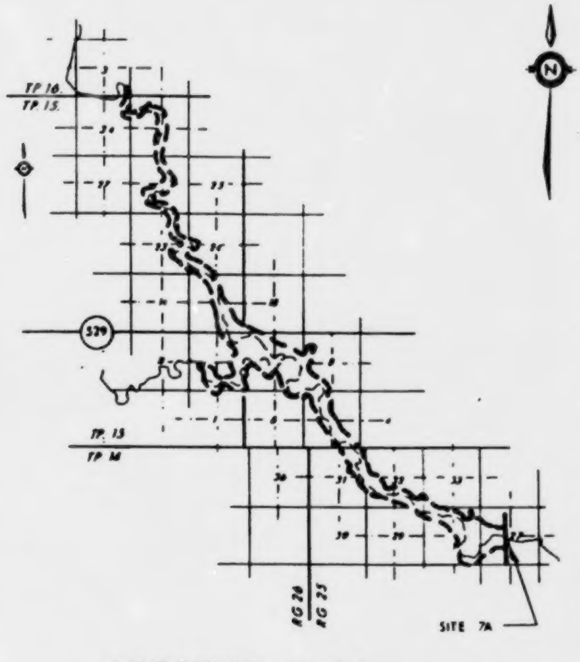
LITTLE BOW SITE 7A 61,700 dam3
(50,000 ac. ft)



FLOODED AREA & CAPACITY CURVES


NORTH ABUTMENT
SOUTH ABUTMENT
970
950
930
910
ELEVATION IN metres
CLAY & SILT
TOD 961.6
FSL 958.6
CLAY
CLAY
SAND & SILT
SAND & SILT
G & S
S
C
S
C
GRAVEL
CLAY
S
SILTSTONE
G
SANDSTONE
CLAYSTONE
0
600
1200
DISTANCE IN metres

VALLEY CROSS SECTION AT DAMSITE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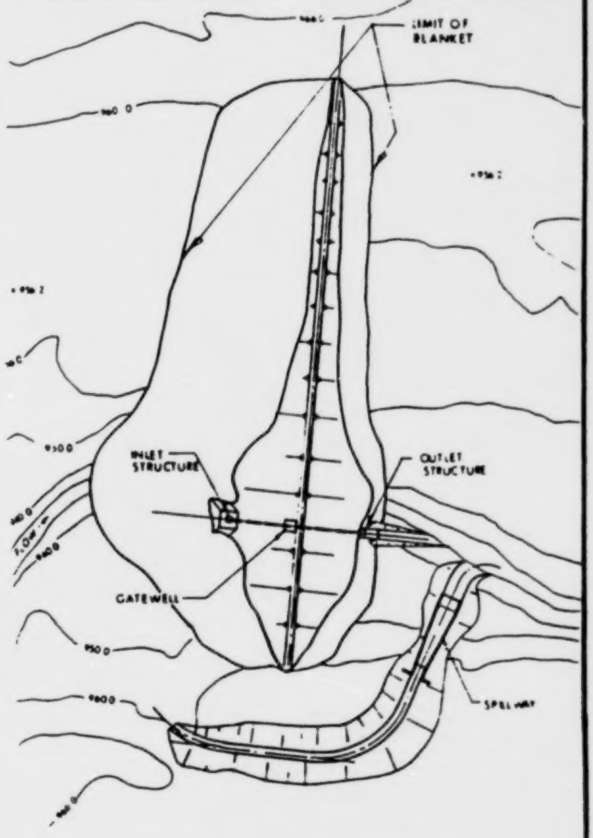
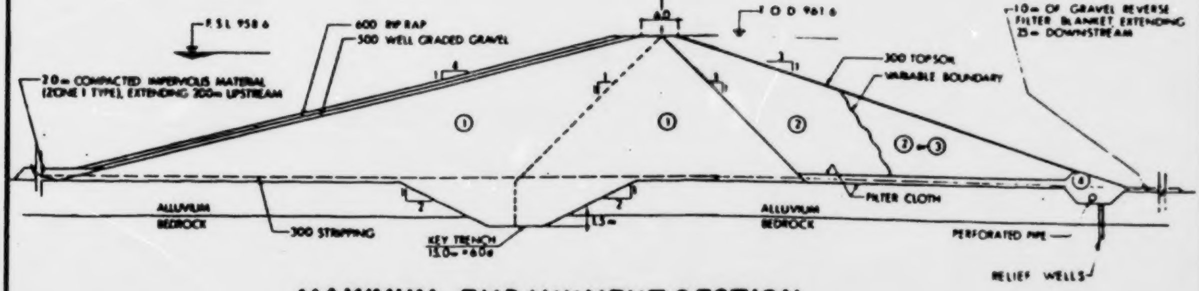
TP 15
3
34
27
23
22
26
529
TP 15
TP 14
36
31
32
33
30
29
RG 26
RG 25
SITE 7A

LOCATION PLAN


N
LIMIT OF BLANKET
960.0
INLET STRUCTURE
OUTLET STRUCTURE
GATEWELL
950.0
960.0
SPILLWAY

SITE LAYOUT


℄ DAM
FSL 958.6
TOD 961.6
600 RIP RAP
300 WELL GRADED GRAVEL
2.0m COMPACTED IMPERVIOUS MATERIAL (ZONE 1 TYPE), EXTENDING 200m UPSTREAM
10m OF GRAVEL REVERSE FILTER BLANKET EXTENDING 25m DOWNSTREAM
300 TOPSOIL
VARIABLE BOUNDARY
①
①
②
② – ③
④
ALLUVIUM
BEDROCK
ALLUVIUM
BEDROCK
300 STRIPPING
KEY TRENCH 15.0m ±60a
1.5m
FILTER CLOTH
PERFORATED PIPE
RELIEF WELLS

MAXIMUM EMBANKMENT SECTION

FIGURE. 3.

TABLE 2
Pertinent Data and Cost Summary
Little Bow Site 7A
86 300 dam^3 (70,000 ac.ft.) Storage Alternative

Reservoir

Full Supply Level (FSL)	961.5 m
Total Storage at FSL	86 300 dam^3
Flooded Area at FSL	1,000 ha
Project Design Flood - 0.5 PMF (inflow)	322.8 m^3/s
Spillway Design Flood - 1:100 (inflow)	147.3 m^3/s
Freeboard at FSL	3.1 m

Embankment

Top of Dam Elevation	964.6 m
Maximum Height	27.6 m
Volume of Fill	1 401 000 m^3

Spillway

Crest Elevation	959.4 m
Radial Gates	3 @ 3.3 m (W) x 2.1 m (H)
Basin Elevation	935.3 m
Design Discharge (1:100 routed outflow)	78.6 m^3/s
Probable Maximum Discharge (0.5 PMF routed outflow)	228.9 m^3/s

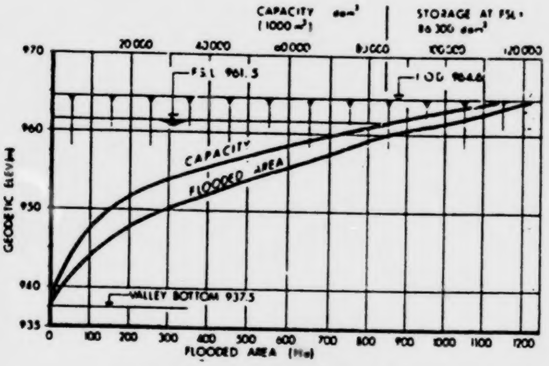
Irrigation Supply Conduit

Conduit Diameter	1.5 m
Irrigation Supply Capacity Requirement	8.5 m^3/s
Gate Size	2 @ 2 m x 2 m
Intake Crest Elevation	942.5 m
Minimum Reservoir Elevation to Pass Irrigation Requirement	943.2 m

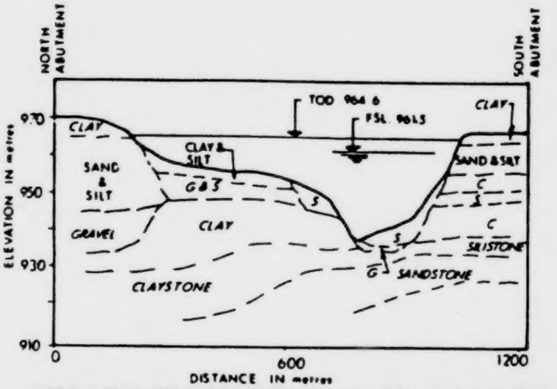
Cost Estimate Summary

Mobilization		$ 100,000
Care of Water		295,000
Embankment		8,610,000
Spillway		1,784,000
Irrigation Supply Conduit		733,000
	Subtotal	$11,522,000
	Contingencies (25%)	2,880,000
	Subtotal	14,402,000
	Engineering (15%)	2,160,000
	Reservoir Costs	8,600,000
	Total Project Cost	$25,162,000

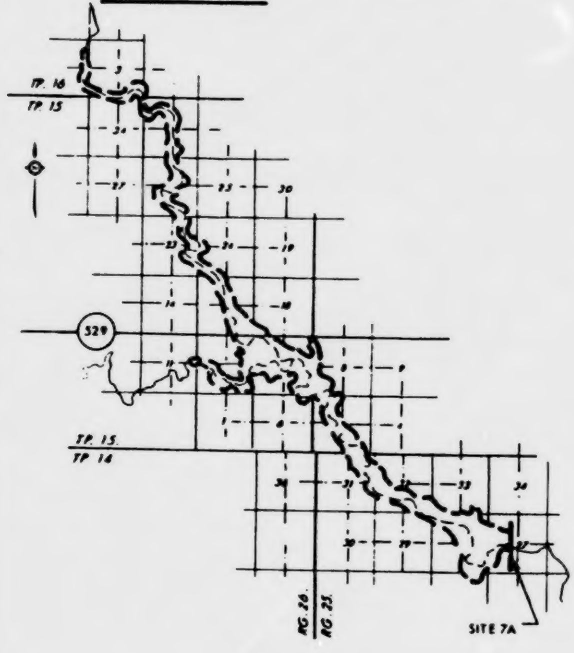
LITTLE BOW SITE 7A 86,300 dam^3
(70,000 ac. ft)



FLOODED AREA & CAPACITY CURVES


NORTH ABUTMENT
SOUTH ABUTMENT
TOD 964.6
FSL 961.5
970
950
930
910
ELEVATION IN metres
CLAY
SAND & SILT
CLAY & SILT
G & S
S
GRAVEL
CLAY
CLAYSTONE
SAND & SILT
C
S
C
SILTSTONE
G
SANDSTONE
0
600
1200
DISTANCE IN metres

VALLEY CROSS SECTION AT DAMSITE


TP. 16
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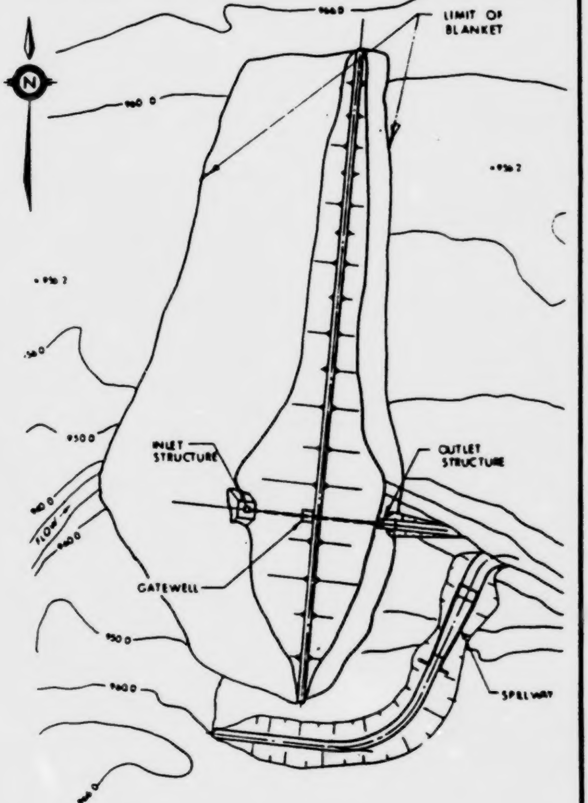
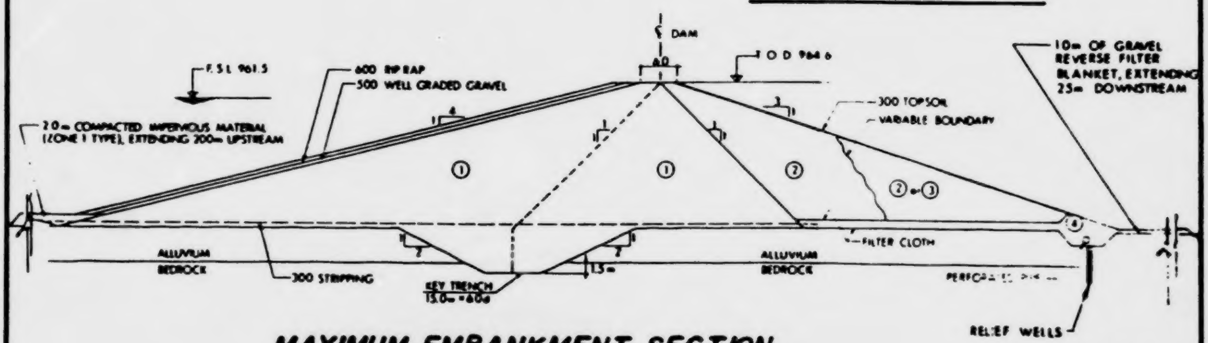
TP. 15
TP. 14
36
31
32
33
34
30
29
RG. 26
RG. 25
SITE 7A

LOCATION PLAN


960.0
LIMIT OF BLANKET
960.0
956.2
956.2
950.0
950.0
INLET STRUCTURE
OUTLET STRUCTURE
FLOW
GATEWELL
950.0
960.0
SPILLWAY
960.0

SITE LAYOUT


℄ DAM
F.S.L. 961.5
T.O.D. 964.6
600 RIP RAP
500 WELL GRADED GRAVEL
2.0m COMPACTED IMPERVIOUS MATERIAL (ZONE 1 TYPE), EXTENDING 200m UPSTREAM
4.0
4
1
3
300 TOPSOIL
VARIABLE BOUNDARY
10m OF GRAVEL REVERSE FILTER BLANKET, EXTENDING 25m DOWNSTREAM
①
①
②
② or ③
④
FILTER CLOTH
ALLUVIUM
BEDROCK
300 STRIPPING
KEY TRENCH 15.0m ± 60d
1.5m
ALLUVIUM
BEDROCK
PERFORATED PIPE
RELIEF WELLS

MAXIMUM EMBANKMENT SECTION

FIGURE. 4.

LIST OF APPENDICES

A - WATER SUPPLY AND HYDROLOGY STUDY
(Nanuk Engineering and Development Ltd.)

B - GEOLOGICAL/GEOTECHNICAL EVALUATION
(Thurber Consultants Ltd.)

C - DETAILED SUMMARY OF DESIGN STUDIES AND COST ESTIMATES

D - RESERVOIR COSTS

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONFLUENCE SITE (7B-1)*
FEASIBILITY DESIGN REPORT
September, 1985

APPENDIX A

WATER SUPPLY AND HYDROLOGY STUDY

*Through special agreement with Nanuk Engineering and Development, the water supply and hydrology investigations which they had carried out for Little Bow Site 7B-1 were also utilized for the current Site 7A study.

Box 817
Cochrane, Alberta T0L 0W0
Telephone (403) 932-3593

NANUK ENGINEERING & DEVELOPMENT LTD.

September 30, 1985

WER Engineering
Horizon 39 Building Box 2 Room 306
2735 39th Avenue NE
Calgary, Alberta
T1Y 4T8

Attention: Jack Wise

RE: LITTLE BOW RIVER BASIN
CONFLUENCE SITE 7B-1, FEASIBILITY STUDY

Dear Jack;

We are pleased to transmit our report on the hydrologic assessment of the confluence site 7B-1. The water supply provided by this reservoir and the flood flows affecting its design have both been addressed. The flood parameters should be regarded as preliminary only and must be substantially improved by additional hydrologic analysis prior to the preliminary design of a reservoir on the site.

M. V. THOMPSON

Yours truly,

M. V. Thompson, P.Eng.
Chief Engineer

MVT:lc
enclosure

PERMIT TO PRACTICE
NANUK ENGINEERING & DEVELOPMENT LTD.
Signature
Date Aug 30, 1985
PERMIT NUMBER: P 2906
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Engineering Design & Drafting, Water Resources Planning,
Commercial, Industrial & Agricultural Projects, Property Development & Subdivision

1.0 WATER SUPPLY

The water supply available to the confluence site 7B-1 consists of natural flows in Mosquito Creek and the upper Little Bow River and diversion through Squaw Coulee and via the Little Bow Canal. The total basin yields provided by the three storage capacity alternatives - 30,000; 50,000 and 70,000 ac-ft. were calculated based on;

1. The water available for diversion from the Highwood River was calculated in accordance with the guideline permitting a total of 60% of the Highwood flow through both diversion canals with a minimum flow of 70 cfs downstream of the Little Bow Canal;

2. The physical capacity of the Squaw Coulee diversion was set at 60 cfs;

3. The capacity of the Little Bow diversion canal was varied from 100 to 500 cfs in 100 cfs increments;

4. The diversion canals were assumed to operate from April 15 to October 15 to provide water for irrigation and to the reservoir;

5. The municipal and riparian flow requirement of 15 cfs will be satisfied during the winter by diversion through the Little Bow Canal;

6. Natural flows were calculated on an annual basis and were assumed to enter the reservoir in April of each year;

7. The draft from the reservoir and Highwood diversions served a variable irrigation demand and a uniform municipal, instream use and residual flow requirement;

8. The seasonal irrigation demand was distributed in accordance with the calculated 1984 withdrawals as follows:

May	8%
June	30%
July	38%
August	19%
September	5%

9. Evaporative losses were calculated based on net evaporation at Calgary with a transfer factor of 1.0.

10. Water demands were distributed upstream and downstream of the reservoir site as follows except when upstream requirements exceeded 7,000 ac-ft. on either branch.

a. Mosquito Creek -	12%
b. Upper Little Bow -	20%
c. Lower Little Bow -	68%

11. Natural flows were calculated in the same manner as detailed in W.E.R. Engineering's report 'Little Bow River Basin, Storage Site Investigation'. The natural runoff in unit area terms are presented in Table I.

1.2 Methodology

The method of evaluation used to critical period 1916 to 1941 to calculate the water balance in the reservoir. The initial part of this period was used to check that the reservoir could be filled by the fall of 1928. The latter part represents the most critical drought within the period of record.

TABLE 1

NATURAL RUNOFF
(ac.ft./sq.mi./year)

YEAR	MOSQUITO CREEK	LITTLE BOW
1916	224	0
1917	263	0
1918	24	2
1919	8	12
1920	132	85
1921	14	15
1922	39	0
1923	144	2
1924	39	3
1925	51	12
1926	93	8
1927	225	31
1928	110	85
1929	114	8
1930	51	9
1931	0	12
1932	76	4
1933	55	13
1934	29	16
1935	21	9
1936	5	31
1937	7	7
1938	81	5
1939	25	12
1940	33	10
1941	16	12
MEAN	72	16

The diversions to the Little Bow Basin from the Highwood River were made in such a manner as to satisfy irrigation demand upstream of the confluence site. The firm supply available to both Mosquito Creek irrigators and those on the upper Little Bow is 7,000 ac-ft. on each reach. This firm supply is based on the distribution of seasonal irrigation demand stated previously and the acceptability of a 50% deficit in water supply in August (10% deficit in annual requirement) once in every 75 years.

The total basin yield provided by three storage levels at site 7B-1 was analyzed for canal capacities varying from 100 to 500 cfs in 100 cfs increments. The diversion guideline of 60% of the Highwood flow with a minimum residual flow in the Highwood of 70 cfs was used in the analysis.

1.3 Results

The results are presented in Figure A-1 in which variation in total basin yield with increasing capacity of the Little Bow Canal is graphed for three reservoir sizes. Observation from these results are;

1. At 30,000 ac-ft. storage capacity an increase in the diversion capacity in the Little Bow Canal above 300 cfs produce no increase in yield.

2. Increasing diversion canal capacity from 100 to 200 cfs increases basin yield by an average of 26% for all storage capacities.

LITTLE BOW CONFLUENCE SITE

SQ @ 60, D/S @ 70, MAX. 60 %

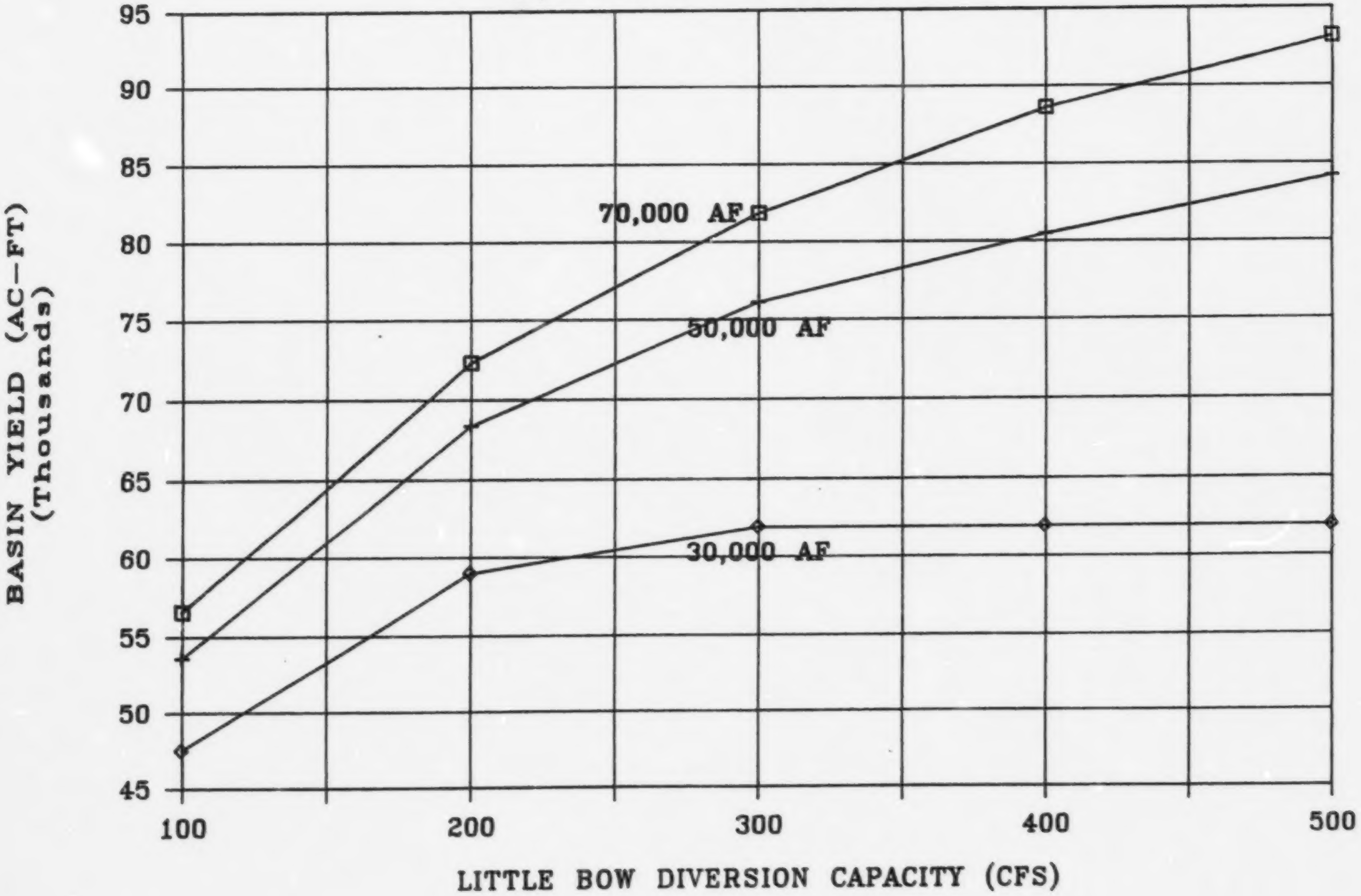


FIGURE A.1

3. Increasing diversion canal capacity from 200 to 300 cfs increase basin yield by an average of 13% for the 50,000 and 70,000 ac-ft. storage sizes. The increased yield for the 30,000 ac-ft. reservoir is 5%.

4. The yield storage relationships at a diversion canal capacity of 300 cfs are;

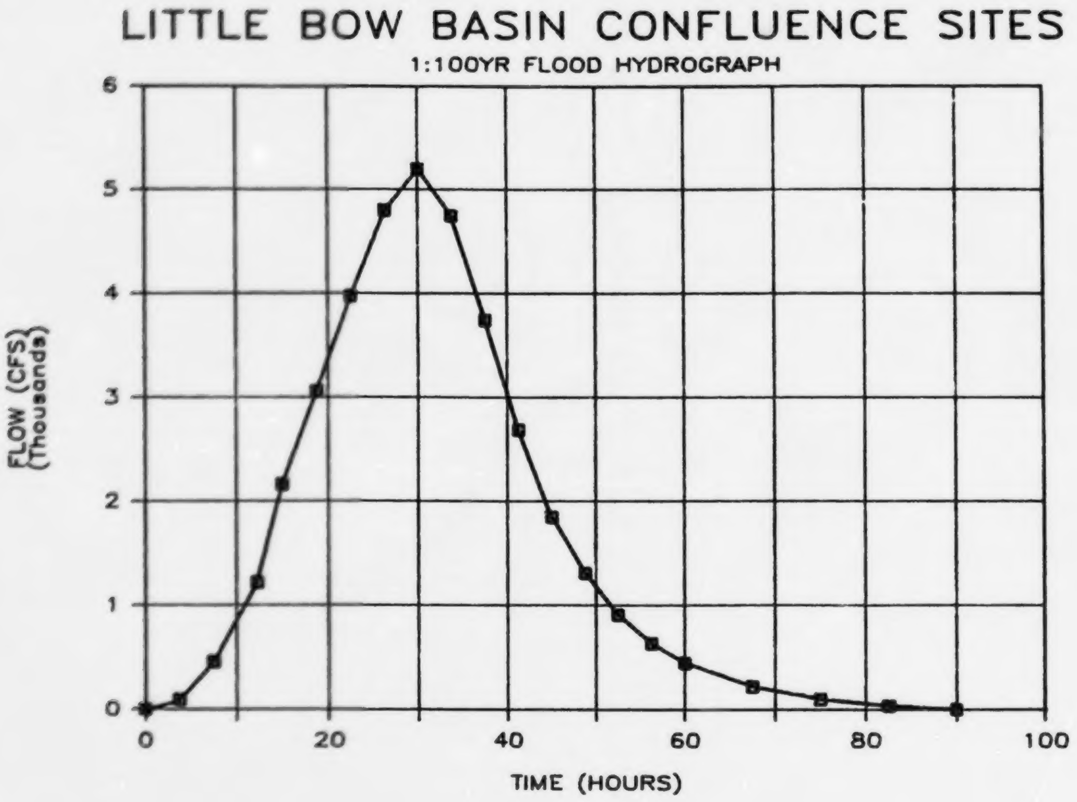
STORAGE ac-ft.	YIELD ac-ft.	Δ YIELD/ STORAGE	Δ YIELD/ Δ STORAGE
0	14,000*	-	-
30,000	62,000	1.6	1.6
50,000	76,000	1.24	0.7
70,000	82,000	0.97	0.30

* deficits in September in one year; 50% deficit in August, 1 year in 75

2.0 FLOODS

The probable maximum flood (PMF) was determined using the SNBB method for prairie streams. The 1 in 25 and 1 in 100 year floods and associated by hydrographs were based on frequency analysis of the recorded maximum mean daily flows of the Little Bow River at Carmangay. The peak instantaneous flows were calculated from the maximum mean daily flow using a historic ratio for recorded flood events.

The flood hydrographs representative of 0.5 of the PMF and the 1 in 100 year flood are presented in Figure A.2. The estimated values of the flood flows are listed below:


LITTLE BOW BASIN CONFLUENCE SITES
1:100YR FLOOD HYDROGRAPH
FLOW (CFS) (Thousands)
0
1
2
3
4
5
6
TIME (HOURS)
0
20
40
60
80
100

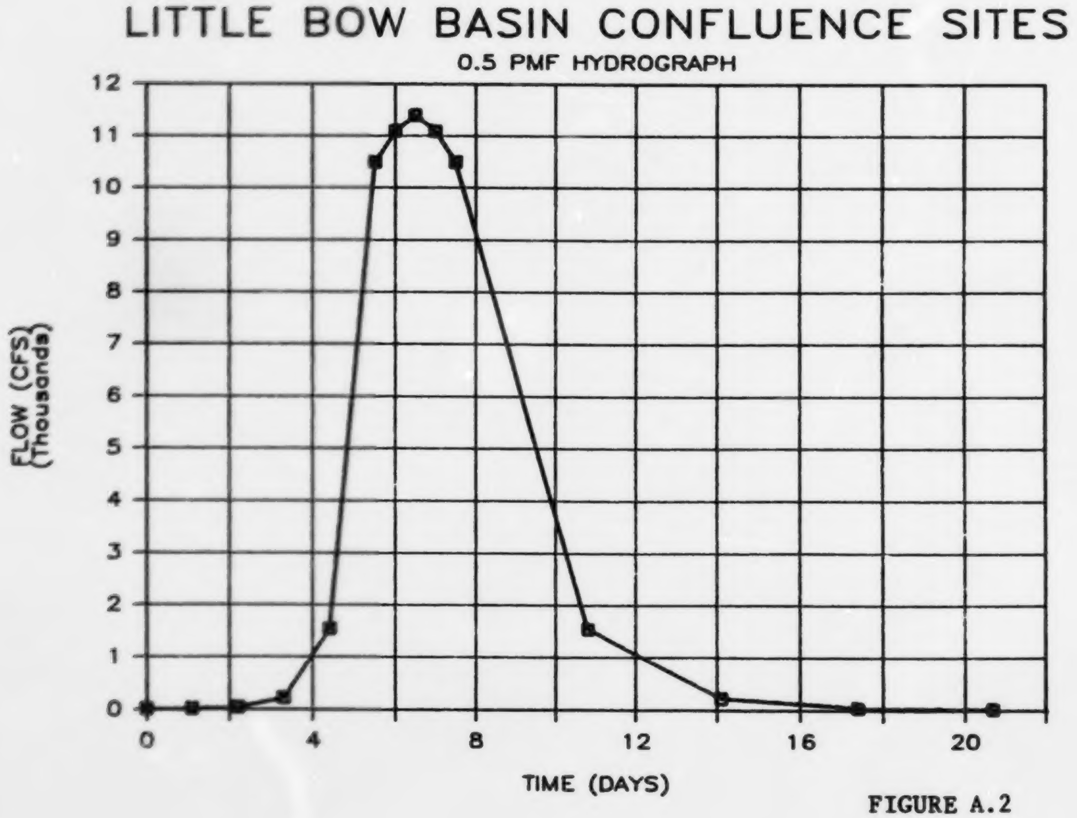

LITTLE BOW BASIN CONFLUENCE SITES
0.5 PMF HYDROGRAPH
FLOW (CFS) (Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (DAYS)
0
4
8
12
16
20

FIGURE A.2

ESTIMATES OF FLOOD FLOWS

Drainage Area (MI2)	PMF Max. Mean Daily (cfs)	100 year Peak Instantaneous (cfs)	25 year Peak Instantaneous (cfs)
455	20,000-25,000	5,200	3,000

The 1:25 and 1:100 year flows are considerably less than those previously estimated for Mosquito Creek, Site 4. The probable reasons for this difference are:

1. Mosquito Creek makes a major contribution to flood flows in the Little Bow below the confluence. Floods in Squaw Coulee, Nanton Creek and the upper Little Bow are relatively small. The combined flood flow, when routed, will produce a lesser peak than estimated for Mosquito Creek Site 4 due to attenuation, but the volume of the flood flow is increased.

2. Mosquito Creek flood flows are overestimated as a result of transposition from Willow Creek.

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
SITE 7A
FEASIBILITY DESIGN REPORT
March, 1986

APPENDIX B

GEOLOGICAL/GEOTECHNICAL EVALUATION

LITTLE BOW RIVER BASIN STUDY
GEOTECHNICAL EVALUATION
SITE 7A

Submitted

to

W-E-R ENGINEERING LTD.

Thurber Consultants Ltd.
Calgary, Alberta

G.C. Morgan, P.Eng.
Review Principal

L. B. SMITH

L.B. Smith, P.Eng.
Review Engineer

N. HERNADI

N. Hernadi, P.Eng.
Project Engineer

PERMIT TO PRACTICE
THURBER CONSULTANTS LTD.
Signature
Date 26 MARCH, 1986
PERMIT NUMBER: P 355
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

March, 1986
File: 19-293-2

SYNOPSIS

subject

This report presents a preliminary geotechnical evaluation of a damsite located on the Little Bow River about 24 km southeast of Parkland, Alberta. The site has been designated as Site 7A. Two different reservoir storage capacities are being considered at this site, and, therefore, 2 different embankment heights have been examined.

field work

A drilling program consisting of 7 test holes drilled along the proposed dam centreline was carried out during January 1986. The drilling program included sampling of the overburden soils and continuous coring of bedrock.

site geology

The stratigraphy at the proposed damsite is relatively complex. At this location, the Little Bow River is about 30 m below the uplands elevation. A high level terrace, about 15 to 20 m above river level is present on the left (north) bank of the river.

Fine to medium sand and silt of glaciolacustrine origin occurs to depths of 18 to 22 m at the abutments on the upland areas. This is underlain by clay till and bedrock on the right (south) side. A stratum of alluvial sand and gravel was found between the glaciolacustrine and clay till strata on the left side.

The high level terrace is mantled with about 3 m of soft to firm silt and clay, overlying alluvial gravel, clay till and bedrock. In the valley bottom sand or gravel alluvium overlies bedrock.

Depth to bedrock in the test holes ranged from about 5 m in the valley bottom to as much as 38 m in the upland area at the left abutment. The bedrock stratigraphy was comprised of siltstone and claystone overlying sandstone. Evidence of glacial ice-thrusting of bedrock was encountered at Site 7A with bedrock found overlying till at 2 test holes. It is possible that much of the claystone and siltstone found above sandstone may be present at this site as a result of ice-thrusting.

reservoir shoreline stability

Three deep seated landslides have been noted along the valley walls 10 to 15 km upstream from the dam embankment, one of which falls within the limits of the proposed reservoir. Detailed geotechnical investigations will be required to assess the effects of reservoir impoundment on the stability of the affected landslide. This work should include an assessment of possible wave generation by landslide activity.

No significant concerns with respect to reservoir shoreline stability were identified in any other locations within the reservoir. Deep seated landslides are possible in some areas, however, the frequency of occurrence of such landslides is expected to be very low. Shallow instability can be expected along the reservoir shorelines due to wave erosion. The beaches are expected to be self stabilizing over 20 to 30 years.

reservoir watertightness

Lateral seepage from the reservoir is not a major concern at this time. A detailed hydrogeological investigation will be required during detailed design in order to confirm this assessment.

embankment siting

Major geotechnical concerns affecting the design and construction of the dam at this location include the presence of significant depths of pervious strata, the significant depth to bedrock, the occurrence of ice-thrusted bedrock and groundwater under artesian pressure.

embankment cross-section

A zoned earth fill embankment has been recommended for both dam embankment heights. A suitable source of clay borrow for use in dam construction has not been identified, however, the configuration recommended here assumes that a source can be located on the uplands within a reasonable haul distance. If a suitable source of clay cannot be identified, then the embankment cross-section proposed here will have to be modified to use larger quantities of locally available materials.

It is recommended that the downstream slopes be constructed at an average 3 horizontal to 1 vertical, while the upstream slopes would be constructed at an average 4 horizontal to 1 vertical. It is anticipated that the slopes can be bermed, with overall average slope angles as given above, in order to reduce the quantity of fill required for the embankments. A decision in this regard will depend on the results of material balance studies, laboratory test results and stability analyses which should be undertaken during detailed design.

The failure mechanism of the three landslides located upstream from the proposed dam site should be established. The results of that work will have an impact on the soil parameters used for the design of the dam embankment. It is possible that the embankment sideslopes may have to be flattened significantly from those recommended here, if the landslides are the result of the presence of weak layers within the bedrock. The presence of ice-thrusted bedrock and its significance should also be examined in more detail prior to final design.

site preparation

Site preparation for dam construction will require removal of organic materials and zones of soft soil. This will involve a requirement to remove up to 3 m of material from the high level terrace on the left bank. Seepage into this excavation is a concern due to the presence of groundwater under artesian pressure in this area.

seepage control

The control of seepage is a major concern at Site 7A. Due to the presence of significant depths of relatively pervious soils in the abutment areas and under the high level terrace, the seepage control measures required will include a positive cutoff, an upstream impervious clay blanket and a downstream reverse filter blanket, together with a conventional toe drain below the embankment. Relief wells will also be required at the downstream toe.

The purpose of the seepage control measures is primarily to maintain structural integrity of the dam, and to reduce seepage quantities. It should be noted, however, that the proposed seepage control measures will not eliminate seepage in the area of the dam.

In view of the significant concerns associated with the control of seepage at Site 7A, it is recommended that a greater than normal contingency be allowed in the cost estimate for this aspect of the dam construction.

spillway

A single spillway, excavated around the right dam abutment is being proposed at this site. The depth of excavation for the spillway will depend on the maximum reservoir operating level ultimately selected. The excavation will be carried out primarily through glaciolacustrine sands and silts. No information on the depth to groundwater within the sands and silts is available in the vicinity of the proposed excavation. Significant construction difficulties will be encountered if the base of the excavation must be taken below the groundwater table.

Provided the groundwater table is below the base of the spillway, permanent slopes in the silty sands should be cut at 3 horizontal to 1 vertical. If the base of the spillway is below the groundwater table, sideslopes will have to be flattened and permanent drainage will have to be installed to ensure the stability of the sideslopes.

The spillway approach channel will be excavated mostly through silty sand. It should therefore be lined with an impervious clay blanket to minimize seepage from the channel.

low level conduit

The low level conduit should be founded either on bedrock, or on compacted silty clay fill which extends below the conduit down to the bedrock. The conduit should therefore be located where the depth to bedrock is a minimum.

concrete

Sources for concrete aggregate have not been confirmed. It is anticipated that suitable aggregate (which will have to be crushed, screened and washed) can be located in the alluvial sediments upstream from the dam site. It is recommended that Type 50 sulphate resistant cement be used for all concrete in contact with soil at this site.

additional geotechnical investigations

Prior to final design, a comprehensive drilling program will be required in order to further delineate subsurface conditions at the proposed site. Other geotechnical studies, as detailed in the report, will also be required.

TABLE OF CONTENTS

Page

SYNOPSIS i

1.0 INTRODUCTION 1

- 1.1 General 1
- 1.2 Project Background 1

2.0 METHOD OF INVESTIGATION 2

- 2.1 General 2
- 2.2 Engineering Terrain Analysis 2
- 2.3 Field Work 2
- 2.4 Laboratory Testing 3

3.0 REGIONAL GEOLOGY 4

- 3.1 Physiography, Relief and Topography 4
- 3.2 Bedrock Geology 4
- 3.3 Buried Valleys 5
- 3.4 Surficial Geology 5
- 3.5 Glacial Ice Thrusting 6
- 3.6 Surface Drainage and Groundwater 6

4.0 GEOTECHNICAL EVALUATION AND RECOMMENDATIONS 7

- 4.1 General 7
- 4.2 Reservoir Geology 7
- 4.3 Reservoir Shoreline Stability 8
- 4.4 Reservoir Watertightness 9
- 4.5 Damsite Geology 10
- 4.6 Dam Embankment 13
- 4.7 Spillway 19
- 4.8 Low Level Conduit 20
- 4.9 Concrete 21
- 4.10 Additional Geotechnical Investigations 21

List of References

APPENDIX A Drawings
APPENDIX B Test Hole Logs

SECTION 1

INTRODUCTION

1.1 General

This report presents the results of a geotechnical evaluation of a dam/reservoir location designated as Site 7A located approximately 8 km downstream of the Mosquito Creek-Little Bow River confluence in the Little Bow River Drainage Basin.

The scope of work for the investigation was based on discussions with Mr. S. Larsen, P.Eng. of Alberta Environment, Planning Division and Mr. J.M. Wise, P.Eng. of W-E-R Engineering Ltd., and was described in a letter to Mr. Wise dated December 6, 1985. Authorization to proceed with the investigation was received at that time from Mr. Wise.

1.2 Project Background

Three potential dam sites located in the Little Bow River Basin below the confluence of the Little Bow River and Mosquito Creek were evaluated in connection with a water storage investigation study undertaken by W-E-R Engineering Ltd. for Alberta Environment Planning Division. The results of this evaluation (including a preliminary geotechnical evaluation) are presented in a conceptual design report which was submitted to Alberta Environment (W-E-R Engineering Ltd., 1985). Based on this report, more detailed engineering studies were undertaken for Site 7B-1, and a report on a feasibility study for Site 7B-1 was submitted to Alberta Environment (W-E-R Engineering Ltd., 1985).

The current investigation represents a feasibility study for Site 7A, to provide Alberta Environment with comparative data for final site selection.

SECTION 2

METHOD OF INVESTIGATION

2.1 General

The scope of this investigation included a review of published and unpublished information concerning the geology and hydrogeology for Site 7A, an engineering terrain analysis for the area, followed by a drilling program along the proposed dam centreline and laboratory testing of soil and rock samples.

2.2 Engineering Terrain Analysis

An engineering terrain analysis of the site was carried out using high and low level airphoto coverage, to assess the geological setting and its implications on construction of the proposed dam.

The analysis included the mapping of surficial soils at the damsite and within the reservoir, identification of slope instability, and the delineation of surface drainage patterns and other pertinent features.

2.3 Field Work

The drilling program was carried out between January 7 and 15, 1986. A total of 7 test holes were drilled along the proposed dam centreline at the locations shown on Drawing 2, Appendix A. All test holes were drilled with a Mayhew 1000 truck mounted rotary drill rig supplied by SDS Drilling Ltd. of Calgary, Alberta. The depth of the test holes ranged between 20.0 and 55.0 m below existing ground surface.

The soil overburden was drilled using a 133 mm tricone rock bit, generally without casing, using water or drilling mud, as required. Soil samples for laboratory testing were obtained by means of Standard Penetration Tests and Shelby tubes.

Bedrock was cored continuously without casing, using the wireline method and a Christiansen triple tube core barrel with water flushing. The 73 mm diameter core was recovered in plastic tubes in 3.0 m core runs. The plastic tubes were sealed in the field, and were returned to the Calgary laboratory of Thurber Consultants Ltd. for logging and testing.

The test holes were logged in the field by examination of Standard Penetration Test and Shelby tube samples, as well as by inspecting the ends of each core run prior to sealing the plastic tubes. In addition, the drilling inspector recorded observations with regard to drill behaviour, drilling rates, caving or sloughing zones, and other pertinent observations.

Standpipe piezometers were installed in 2 test holes in order to obtain further information on groundwater levels in the area. Pneumatic piezometers were sealed in the bedrock in 2 test holes.

All test holes were backfilled with grout. Two test holes produced groundwater flow under artesian pressure, and attempts were made to seal these holes at the completion of the field work.

The locations of test holes in both abutment areas were determined relative to existing fence and section lines. All remaining test holes were located on the line joining the two test holes on the abutments. The ground surface elevations at the test holes was obtained by plotting the test hole locations on a 1:10,000 scale topographic plan with 2 m contour intervals.

The test hole logs are presented in Appendix B.

2.4 Laboratory Testing

Laboratory tests on all soil samples included visual classification and water content determinations. Additional tests included grain size analyses, Atterberg Limits tests, Penetrometer tests as well as bulk and dry unit weight determinations for relatively undisturbed Shelby tube samples.

Bedrock cores were logged and visually classified in the laboratory, and selective representative samples were taken for moisture content tests, bulk and dry unit weight determinations, Atterberg Limits tests and grain size analyses.

All laboratory test results are presented in Appendix B on the test hole logs, or separately, as applicable.

SECTION 3

REGIONAL GEOLOGY

3.1 Physiography, Relief and Topography

The area of interest is situated within the Alberta Plain physiographic division of the Interior Plains. Its location, some 24 km southeast of Parkland, Alberta, is shown on Drawing 1, Appendix A.

Overall, the terrain within the study area slopes gently from west to east. Elevations average about 960 to 970 m above sea level. Superimposed onto this gently sloping plain is a series of generally northwest-southeast trending ice-marginal meltwater channels. These channels, one of which is followed by the Little Bow River, are incised to depths of 10 m to 30 m below the surrounding general prairie level.

Gently undulating to rolling topography (developed on glaciolacustrine and moraine deposits) is characteristic of most of the terrain in the vicinity of the Little Bow River valley. Typically, slopes range up to about 15 degrees, with steeper slopes (up to 40 to 50 degrees) along the walls of the meltwater channels. Around Clear Lake, a short distance to the west, areas of ridged and hummocky terrain exist. These are developed on materials of glaciofluvial esker and kame origin.

3.2 Bedrock Geology

Published information suggests that the Upper Cretaceous Horseshoe Canyon Formation is the uppermost bedrock unit in the vicinity of Site 7A (Green, 1982; Irish, 1967). However, the site lies close to both the transitional boundary between the Horseshoe Canyon and St. Mary's Formations as well as to the contact between these units and the overlying Upper Cretaceous-Tertiary Willow Creek Formation. The geological formation to which the bedrock strata at this site belong is, thus, uncertain.

The drilling program at Site 7A indicates that the bedrock comprises an interbedded sequence of non-marine siltstones and clay shales. Interbeds of fine to medium sandstone are present also. Minor constituents include bentonitic sandstone and bentonite.

At Site 7A, bedrock apparently occurs at or below river level. As detailed in Section 3.5, there is evidence that ice-thrusting of the uppermost bedrock material has taken place in the area.

3.3 Buried Valleys

An extensive network of river and stream valleys was developed in southern Alberta in pre-glacial times. These valleys were cut down into bedrock and have subsequently been infilled by a thick surficial overburden sequence that may include a thick basal sand and gravel unit.

The Tee Pee Valley, the thalweg for which is indicated on Drawing 1, Appendix A (after Geiger, 1968), is most important within the study area. It is believed to lie to the south of the Little Bow River valley in the area of Site 7A. The drilling program in the proposed dam site area did not disclose evidence for the presence of a buried valley at Site 7A.

3.4 Surficial Geology

Surficial materials of both glacial and postglacial origin occur in the vicinity of Site 7A.

Two types of surficial deposits are dominant within the area of interest. Glacial till (a heterogeneous mixture of clay to boulder size material) was laid down by glacier ice and forms areas of ground and hummocky moraine. Glaciolacustrine silts and sands (laid down in a preglacial lake, that developed as the ice retreated) are also prevalent. Silts, sands and gravels of glaciofluvial origin (deposited by glacial meltwater as eskers and kames) are widespread in the area of Clear Lake, a short distance west of the Little Bow River valley.

Since deglaciation of the area, postglacial erosional and depositional processes have given rise to the development of a variety of more recent deposits. Most important are alluvial materials, that form floodplain, terrace and fan deposits within the meltwater channels, and colluvium (gravity-transported debris forming a slopewash veneer on steeper slopes in the area). Locally, recent lake deposits and wind-blown silts and sands (forming dunes in some areas) are also present.

Surficial material thicknesses are quite variable within the area of interest. In the vicinity of Site 7A, depths to bedrock are typically in the range of 30 to 40 m beneath prairie level. Thinner surficial overburden (10 to 20 m thick) exists adjacent to other sections of the Little Bow River valley, while considerably thicker surficial materials may exist within the buried preglacial channels.

3.5 Glacial Ice Thrusting

Evidence of glacial ice-thrusting of bedrock and overlying surficial materials is widespread in southern Saskatchewan (Christiansen and Whitaker, 1976) and, though less well-documented, in southern Alberta. Ice-thrusting is most prevalent close to glacier margins where, according to Sauer (1978), the:

> "glacier is forced into compressive flow ... and ... under the right conditions, the underlying sediments may be carried up into the ice and folded and sheared, resulting in complex structures after ablation ..."

There is evidence of ice-thrusting in the vicinity of Site 7A. Bedrock was encountered overlying till in two test holes. This situation is interpreted to be related to thrusting by glacier ice.

3.6 Surface Drainage and Groundwater

As noted, the area of interest is drained by a series of generally northwest to southeast trending streams. Of these, the Little Bow River and Mosquito Creek are amongst the most important. Generally, the rivers and creeks form underfit streams within ice-marginal meltwater channels. Mostly, surface drainage and runoff is into these water courses; however, local drainage also occurs into closed topographic depressions, whence it either evaporates or seeps into the ground.

Three groundwater flow regimes, one superimposed on the other, are identified. On a regional scale, groundwater flows at depth, from recharge areas in the Foothills and Rockies to discharge further east in the Plains. On a smaller scale, local groundwater flows are recharged in the higher sections of the area and discharge into the river and creek valleys. Finally, perched flows exist within granular, and more permeable, overburden zones and at the overburden-bedrock contact. These latter discharge into terrain depressions, as well as the river and creek valleys.

SECTION 4

GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

4.1 General

Little Bow Site 7A is located approximately 24 km southeast of Parkland, Alberta, as shown on Drawing 1, Appendix A. The proposed damsite is located in Section 27, Township 14, Range 25, West of the 4th Meridian.

It is understood that two possible storage capacities are being considered, with the following parameters:

Reservoir Capacity (dam3)	Full Supply Level (m)	Freeboard (m)	Top of Dam Elevation (m)	Flooded Area (ha)	Draw Down (m)
61,700	958.6	3.0	961.6	790	7
86,300	961.5	3.1	964.6	980	9

The maximum embankment height will range between about 25 and 28 m, and the crest length between 840 and 890 m.

As indicated above, the normal operating drawdown will range from about 7 to 9 m, depending on the reservoir storage capacity being considered. Maximum live storage drawdown, which may occur once per 25 years, would be to the top of the low level outlet in each case.

A concrete chute spillway would be constructed around the right abutment of the embankment. A 1.5 m diameter, precast concrete low level conduit would be located near the base of the embankment.

4.2 Reservoir Geology

The surficial geology of the reservoir is shown on Drawing 3, Appendix A. The reservoir outline indicated is that required for the largest proposed storage capacity (86,300 dam3).

Ground moraine, consisting of silty clay till, often overlain with a veneer of glaciolacustrine silt and sand, is the nearsurface soil on the uplands adjacent to the northern section of the proposed reservoir. South of the Little Bow River-Mosquito Creek confluence, the glaciolacustrine sediments become thicker and glaciolacustrine plain predominates. As shown on Drawing 3, high level alluvial terraces are also present locally. These terraces consist of interbedded sand, silt and minor gravel, usually underlain by clay till. The valley bottom areas are infilled with recent alluvial deposits, primarily silt and sand with some gravel, while a veneer of colluvium exists on most slopes.

In the northern portion of the proposed reservoir, the Little Bow River valley has been cut down through glacial till into bedrock. Sandstone and shale are exposed locally in outcrops but generally occur beneath a thin veneer of colluvium (slopewash). Available information suggests that in the southern portion of the proposed reservoir, (in the vicinity of the proposed dam centreline, for example), bedrock occurs close to or below present river level.

The valley walls throughout the area of interest are relatively steep (ranging up to 45 degrees) and generally stable. Evidence of relatively deep seated slope instability exists, however, on the walls of the Mosquito Creek valley (just upstream of the proposed reservoir limits) and along the Little Bow River approximately 10 and 15 km northwest of the dam site. The locations of these landslides are shown on Drawing 3 in Appendix A. Shallow localized instability of the colluvial materials also occurs in a few locations within the proposed reservoir limits, particularly where the Little Bow River and Mosquito Creek are eroding directly at the toe of the valley walls.

4.3 Reservoir Shoreline Stability

There will be an overall decrease in valley wall stability due to the presence of the reservoir. This will be the result predominantly of rapid drawdown and wave erosion. In addition, there will be a tendency for the stability of slopes to decrease as irrigation of the adjacent uplands increases following reservoir development. While these impacts may be significant in localized areas, it is expected that the valley slopes should remain generally stable.

The stability of the deep seated large scale landslide identified at the north end of the reservoir is of concern. A detailed evaluation of the risk and consequences of instability at this location should be undertaken during detailed design. This work should include an evaluation of possible wave generation by landslide activity. The deep seated landslides on the walls of the Mosquito Creek valley are upstream of the proposed reservoir limits and would not be a concern with regard to reservoir shoreline stability.

The limits of any new deep seated slope instabilities which occur following reservoir development are expected to be confined within a zone described by a line drawn parallel to the valley at a distance of about 30 m back from the top of the valley walls. This setback should be reviewed for site specific cases.

It is expected that the reservoir full supply level will be above the overburden-bedrock contact for both possible development scenarios. As a result, erosion along the shoreline should be anticipated. Localized, small scale, instabilities will likely develop in colluvium, where it overlies clay till, and where sand (of glaciolacustrine or glaciofluvial origin) is present. Such instability is expected to be self-healing, as beaches develop over a 20 to 30 year period. The instability should be confined to the range of drawdown in the reservoir.

4.4 Reservoir Watertightness

Detailed data concerning groundwater elevations adjacent to the proposed reservoir are not available. Information from small scale hydrogeological maps for the area, however, indicates that regional groundwater table elevations range from about 960 to 975 m above sea level (Ozoray and Lytviak, 1974). On this basis, and assuming reservoir full supply levels of 958.6 m and 961.5 m, it is not expected that the reservoir will have a significant effect on the regional groundwater table. The groundwater table in the immediate vicinity of the reservoir can, however, be expected to rise.

Some lateral seepage into or out of the valley walls will undoubtedly occur, primarily through joints and fractures in the bedrock, as well as through the more pervious clean sandstone beds. In view of the anticipated existing high regional groundwater table, however, leakage from the reservoir into the valley walls is not expected to be significant. More detailed information concerning existing groundwater levels in the vicinity of the reservoir should be obtained in order to confirm this assessment.

The approximate location of the buried pre-glacial Tee Pee Valley, as mapped by Geiger (1968) based on available subsurface information, is shown on Drawing 1, Appendix A. As indicated on the drawing, the buried valley parallels the modern valley and may intersect it at one or more locations within the proposed reservoir. Information relative to the nature of the valley infill where it intersects the proposed reservoir is lacking. However, assuming the groundwater table within the valley is consistent with information from the small scale hydrogeological maps, it is speculated that seepage losses into the buried valley will not be significant. A detailed investigation to determine the subsurface stratigraphy within the buried valley is recommended, before a final decision is made to proceed with dam construction at this site.

4.5 Damsite Geology

4.5.1 Surface Conditions

The distribution of surficial deposits and other pertinent features at Site 7A is presented on Drawing 4 in Appendix A.

At this site the Little Bow River flows in an easterly direction. The river is located along the north edge of a U-shaped valley which has a base width of about 150 m.

The main valley is located about 30 m below the level of the uplands to the north and south. A gently sloping terrace, rising approximately 10 m to the north over a 450 m width is located between the 13 m high left abutment and the north uplands. Most of this terrace is under cultivation, however, its most northerly portion is a swampy area which is unsuitable for farming and which appears to be an area of groundwater discharge. An extensive area of groundwater discharge also occurs further south on the left bank of the river.

The left abutment sideslope at the centreline of the main valley ranges between about 3 horizontal to 1 vertical and 6 horizontal to 1 vertical. The abutment on the right side at the centreline has a sideslope of approximately 6 horizontal to 1 vertical. Natural valley slopes in the general area of Site 7A can be as steep as 1.5 horizontal to 1 vertical for slopes under 15 m in height. Typically slopes over 15 m in height average 2 horizontal to 1 vertical or flatter.

Sandstone is exposed along the proposed dam centreline on the left abutment, however, subsurface conditions at this location indicate that the sandstone may be an ice-thrusted block. With the exception of this outcrop, the valley slopes near the damsite are veneered by slope wash, generally masking the underlying parent soil. The valley bottom contains recent alluvial deposits of varying texture.

4.5.2 Subsurface Conditions

Subsurface conditions at the damsite are shown in cross-section on Drawing 5, Appendix A. Drawing 5 shows the cross-section drawn with an exaggerated vertical scale in order to present subsurface conditions in more detail. The following major stratigraphic units were encountered at the site:

- glaciolacustrine deposits
- alluvial deposits
- clay till
- bedrock

Glaciolacustrine Deposits

Glaciolacustrine deposits were encountered to depths of 18 to 22 m on both upland areas, as shown on Drawing 5, Appendix A. The glaciolacustrine deposits consist of firm to very stiff silty and sandy clay, overlying fine to medium sands which contain interbedded silt and clay layers.

Alluvial Deposits

Alluvial materials of highly variable consistency and texture were encountered on the high level terrace on the north side and the valley bottom, as well as below glaciolacustrine deposits on the north uplands, as indicated on Drawing 5.

Alluvium on the high level terrace is comprised of silt and clay overlying silty gravel and sand to a depth of 7.6 to 10 m.

Fine to medium silty sands of alluvial and colluvial origin mantle the valley slopes and the valley bottom, and alluvial gravel was encountered in the valley bottom. The thickness of alluvial materials in the valley bottom was found to range from 5 to 6 m.

Clay Till

As shown on Drawing 5, silty and sandy clay till of very stiff to hard consistency was found to overlie bedrock on the uplands and on the high level terrace. The depth to the till stratum and its thickness is highly variable. This is due to the presence of ice-thrusted blocks of bedrock over most of the site, and the thick sequence of alluvial deposits on the north uplands.

Bedrock

The bedrock at Site 7A consists of interbedded sequences of fresh water sandstone and mudrocks (claystone and siltstone). Bedding is essentially horizontal and the mudrocks are often red-stained suggesting that the bedrock is of the Willow Creek Formation from the Upper Cretaceous-Tertiary Age (Green, 1970).

A mudrock sequence 3 to 17 m thick is present below the dam site. The mudrocks are underlain by a massive sandstone bed averaging approximately 10 m thick. Underlying the sandstone is another mudrock sequence whose full depth was not explored during this study. The following evidence indicates that the mudrocks overlying the sandstone are at least two blocks of bedrock which have been ice-thrusted by glacial action, up on to the intact sandstone bed:

1) Glacial till was encountered between bedrock units in test holes TH 86-4, TH 86-5 and TH 86-7. In TH 86-5 and TH 86-7, till was found at the mudrock-sandstone contact. However, in TH 86-4, till exists between mudrock beds.

2) As illustrated in Drawing 5, the upper surface at the sandstone bed slopes up towards the south from below 911.5 m elevation in TH 86-1 to 933.2 m elevation in TH 86-6. This parallels the assumed southwesterly direction of glacial advancement for the area. The upper contact of the sandstone bed would, therefore, be the erosional surface along which the thrust blocks were moved.

The mudrocks can be black, grey, blue-grey or brown-grey and contain occasional bentonitic beds and concretion pebbles. They are generally very weak, fissured and highly weathered. Discontinuities include slightly bentonitic soft clay/silt seams; short, randomly oriented slickensides; and brecciated zones. The bentonitic materials are believed to be of only limited extent and no evidence was found that indicates that continuous layers occur. Contortion of the once horizontal bentonite beds is likely a result of the glacial ice-thrusting.

The massive sandstone is grey, fine to coarse grained and can be silty and/or calcareous. It is, in general, very strong, well cemented and slightly weathered but includes poorly cemented, moderately weak layers. Occasional sandy, siltstone interbeds were also encountered.

Bedrock properties encountered in the test holes, and resulting from laboratory tests are presented on the test hole logs in Appendix B.

Groundwater

A preliminary assessment of groundwater conditions at Site 7A is based on site observations at the time of drilling and a subsequent set of readings taken on piezometer installations.

In the left abutment area, groundwater discharge, defined by extensive icings observed at the time of drilling, occurs below the high level terrace.

Groundwater under artesian pressure was encountered during drilling in the northern portion of the high level terrace on the north side of the valley bottom, at a depth of about 5.4 m below ground surface. This flow originated from an alluvial gravel layer underlying clay.

Artesian flow was also encountered in the valley bottom. It is possible that the aquifer in this case is the sandstone bedrock, although this was not confirmed at the time of drilling.

Initial readings in two pneumatic piezometers sealed in the bedrock have been taken, indicating piezometric levels above the elevation of the overburden-bedrock interface. However, groundwater conditions at these sites, which would have been disturbed by the wet drilling method, may not have stabilized at the time of these readings.

A detailed hydrogeological assessment of the site has not been undertaken, and such a study is recommended for final design.

4.6 Dam Embankment

4.6.1 Siting

A number of significant geotechnical concerns affecting the design and construction of the dam embankment at this location were identified, including:

- The presence of significant depths of pervious strata below the north terrace and in the abutment areas,
- the significant depth to bedrock over most of the site,
- the occurrence of ice-thrusted bedrock, and
- groundwater under artesian pressure.

In view of the preliminary nature of this investigation, additional drilling and test pitting would be required to further delineate subsoil and groundwater conditions, and to provide a more reliable assessment with respect to construction difficulties associated with deep excavations.

4.6.2 Embankment Configuration

Tentative configurations for the proposed dam embankment are presented in Appendix A, Drawings 6 and 7 for the 2 proposed storage capacities. It is expected that the configurations presented on these drawings would be refined and optimized during detailed design, as a result of material balance studies and detailed slope stability analyses.

An average upstream slope of 4 horizontal to 1 vertical is recommended, with an average downstream slope of 3 horizontal to 1 vertical. Both the upstream and downstream slopes may be bermed, with overall average slope angles as given above, in order to reduce the volume of material required. A decision in this regard would be made during the detailed design phase.

As mentioned earlier, a number of deep seated landslides exist on Mosquito Creek approximately 10 km northwest, upstream from the proposed dam site. As well, one deep seated slide has been identified along the Little Bow River some 15 km upstream of Site 7A. These landslides are believed to be seated in overburden, however, this has not been confirmed. If the landslides prove to be seated in bedrock, this would indicate the bedrock may contain pre-existing failure surfaces. If this is the case, and if numerous failure surfaces are found in cores obtained from the damsite during further detailed site investigations, then the embankment slopes may have to be flattened significantly from those recommended here. Furthermore, the presence of ice-thrusted bedrock at Site 7A and its significance on the dam embankment design should be examined in more detail prior to final design.

As indicated on Drawings 6 and 7, it is assumed that the upstream portion of the dam (Zone 1) would be constructed of low to medium plastic clay till.

Sources of significant quantities of borrow material for the relatively impervious Zone 1 material, and for the upstream clay blanket are not available at shallow depth within the damsite area itself.

The airphoto interpretation and terrain typing data indicate that the surficial soils in the upland areas adjacent to the damsite are comprised predominantly of glaciolacustrine deposits, which may not be suitable for Zone 1 material. Therefore, suitable borrow sources for Zone 1 material need to be defined by further investigations. In any event, it should be noted that large borrow pits outside of the reservoir area, and possibly as much as 2 to 3 km or further removed from the dam site, may be required to obtain suitable material for Zone 1 and for the upstream blanket.

If a suitable source of clay borrow cannot be located within a reasonable haul distance, then the cross-section of the dam will have to be modified. For example, depending on the location of the clay borrow, a dam cross-section which consists of a clay core and upstream/downstream shells consisting of silty sands, from the adjacent uplands may be more economical.

The downstream portion of the dam (Zones 2 and 3) would be constructed of random semi-pervious to pervious sands and gravels taken initially from the cutoff excavation and possibly the spillway excavation. Additional material for this portion of the dam would have to come from borrow sources located on the high level terrace and the uplands. The coarser and more pervious materials should be placed towards the downstream face of the dam.

As noted, the exact boundaries of the various zones can be modified to make optimum use of the available materials.

Clean sand and gravel would be placed to form the toe drain, as shown on the drawings. This material may be available within the alluvium, however, it may be necessary to screen and wash the pit run gravels in order to obtain material meeting the required specifications. Filter cloth should be used, as indicated on the drawings, to prevent migration of fines into the toe drain.

As a preliminary estimate, it can be expected that the dam foundation will settle in the order of 0.3 m or so during construction. The dam crest would settle an additional 0.15 m or so when the reservoir is filled. It may be desirable to raise the finished dam crest above the design elevation in order to accommodate movements of this order. If required, a detailed settlement analysis of the embankment can be undertaken during detailed design.

4.6.3 Site Preparation

All organic material and all soft or loose inorganic materials should be stripped from below the area of the embankment and the area of the downstream reverse filter blanket. The entire area should be scarified and recompacted to a depth of at least 0.3 m. Proof rolling is recommended prior to placing fill in order to identify any soft zones. Waste soil should be placed upstream of the dam outside of the area of the upstream blanket, preferably in the existing river channel.

Site preparation for the dam embankment will require removal of up to 3 m of soft to firm clay on the north high level terrace. Seepage into this excavation is a concern due to the presence of groundwater under artesian pressure in this area. It is possible that the clay is so soft that it would have to be excavated using a dragline. It is recommended that a number of test pits be excavated on the north terrace in the area of the dam embankment to assess conditions likely to be encountered during stripping operations.

4.6.4 Seepage Control

As previously noted, the control of seepage is a major concern at Site 7A. Due to the presence of significant depths to relatively pervious soils in the abutment areas as well as under the high level terrace, the following seepage control measures will be required:

- A positive cutoff extending into clay till or bedrock below the embankment extending from the north end of the high level terrace to the toe of the right abutment will be required.
- An upstream impervious clay blanket extending from the left abutment area north of the high level terrace to the right abutment will be required in order to reduce seepage through the sands which are present north and south of the dam abutments.
- A downstream reverse filter blanket, together with pressure relief wells, will be required to prevent piping of the sands which are present north and south of the dam abutments.

A positive cutoff, extending into clay till or bedrock below the embankment is recommended along the full length of the dam centreline. The cutoff should have a base width of a minimum 9 m. The width of the cutoff could be increased, as desired, in order to obtain the required quantities of gravel for use in the downstream toe drain or the downstream reverse filter blankets.

Groundwater under artesian pressure was encountered at two test holes. Therefore, seepage into the cutoff excavation is a concern, both in the valley bottom and on the north terrace. It may be necessary to dewater the gravels below the north terrace and the river valley using perimeter wells, in order to proceed with excavation. It is recommended that a number of test pits be excavated along the centreline of the cutoff in order to provide a better assessment of the behaviour of excavation sideslopes.

Seepage through fractures and joints in the bedrock below the dam in the valley bottom is a concern. Pressure relief wells should be installed along the downstream toe of the dam at 25 m intervals, and should extend to a depth of approximately 10 m, to relieve potential uplift pressures.

The upstream impervious blanket should consist of a 2 m compacted layer of clay or clay till. This should be overlain by a 0.6 m layer of compacted random fine grained fill, such as silt and fine sand to provide protection for the clay layer, in the event that cracks form in the clay due to freeze-thaw or dessication. The upstream blanket should be placed across the valley between the top of dam elevation at both abutments and should extend a minimum 200 m upstream from the upstream toe of the dam.

The downstream reverse filter blanket should consist of a 1 m layer of select gravel placed across the valley between the full service level elevations at both abutments, and should extend a minimum 25 m beyond the downstream toe of the dam.

Evidence of the potential presence of the buried Tee Pee Valley, which is known to be located in the general area of this site, was not found during this drilling program. Therefore, seepage into the buried Tee Pee Valley is not a concern at this time.

Whereas the purpose of the recommended seepage control measures is primarily to maintain structural integrity of the dam and to reduce seepage quantities, it should be noted that these measures will not eliminate seepage in the area of the dam.

In view of the significant concerns associated with the control of seepage at Site 7A, it is recommended that a greater than normal contingency be allowed in the cost estimate to provide for additional requirements potentially identified during final design, and for unforeseen difficulties arising during construction.

4.6.5 Upstream Slope Protection

The upstream face of the dam must be armoured in order to reduce possible wave erosion. As indicated on Drawings 6 and 7, the slope protection should consist of 0.5 m of well graded sand and gravel covered by 0.6 m of rock armour. The class of rock armour required will be established during detailed design.

A suitable source of rip rap slope protection has not been established.

An alternative to rip rap is to use coarse pit run gravel and accept the need for occasional regrading of the slopes. The use of soil cement could also be considered.

4.6.6 Downstream Slope Protection

Measures will be required to prevent erosion of the downstream face of the embankment due to surface runoff. The crest of the dam should be surfaced with gravel (for trafficability) and sloped towards the reservoir. The downstream face of the embankment should be covered with 0.3 m of topsoil and hydro-seeded.

4.7 Spillway

Construction of the spillway approach channel around the right abutment will require an excavation mostly through silty sands. It is possible that bedrock will be encountered along some portions of the spillway excavation, particularly at lower elevations on the valley slopes.

No information on the depth to groundwater within the sands and silts below the uplands along the proposed spillway centreline is available. Significant construction difficulties will be encountered if the base of the excavation must be taken below the groundwater table. Further investigations by means of drilling and test pitting would be required to delineate soil and groundwater conditions along the spillway alignment.

Provided the base of the spillway is above the groundwater table, permanent cutslopes in the silty sands should be no steeper than 3 horizontal to 1 vertical in order to ensure long term stability. Flatter sideslopes may be desirable in order to liberate more material for use in the construction of the embankment. Flatter permanent sideslopes and permanent drainage works will be required if the base of the spillway is below the groundwater table.

Permanent cutslopes within shale or sandstone bedrock, if encountered, could be trimmed at 1 horizontal to 1 vertical or steeper and they would remain stable. However, to preclude major maintenance problems due to weathering and erosion, permanent slopes in bedrock should be cut no steeper than 2 horizontal to 1 vertical. If steeper slopes are required, surface treatment, such as shotcreting should be considered.

It is understood that the spillway chute will be lined with concrete in order to prevent erosion. It is also understood that the gradient for the spillway chute cannot exceed 3 horizontal to 1 vertical for hydraulic reasons. This slope should be satisfactory from a slope stability point of view in the sands, silts and clays likely to be encountered in the excavation. This slope would also be satisfactory in the bedrock.

In view of the abundance of fine sand in the area of the spillway, seepage and piping of the sand below the spillway is a major concern. Uplift of the spillway is also a concern. Control of seepage upstream of the spillway should be provided by means of concrete cutoffs at the head of the spillway, as well as at selected intervals along the spillway chute. In addition, the spillway approach should be lined with a 2 m thick impervious clay blanket to minimize seepage from this channel.

It will be necessary to anchor the spillway chute to the slope, and to install suitable drainage below the chute to prevent uplift due to water pressure.

It is understood that the concrete weir and gate structure at the top of the spillway chute will be subjected to horizontal loads, which must be transferred to the underlying soils. For preliminary design of the weir, a nominal angle of friction of 20 degrees may be used for the sand, silt and clay subsoils present in this area. This value should be confirmed during detailed design.

The underlying soils can be expected to rebound due to the weight of material removed from the spillway excavation. Rebound will be primarily elastic and will therefore take place as the excavation proceeds. Past experience with deep excavations in materials similar to those encountered here, indicates that all rebound (including time dependent rebound) will be essentially complete 2 to 3 months after the excavation is completed. The total rebound will range from 30 to 80 mm. A more precise estimate of the rebound can be made once the configuration and depth of the excavation has been confirmed.

4.8 Low Level Conduit

In view of the highly variable compressibility of the alluvial sediments at this site, it is recommended that the low level conduit be founded in bedrock. If this is not possible due to elevation restrictions, it is recommended that all alluvial material below the low level conduit through Zone 1 be subexcavated down to bedrock, and replaced with well compacted clay till. In either case, it is desirable to place the conduit in a location where the depth to bedrock is at a minimum. The available subsurface data indicate that the most suitable location is on the south side of the river channel.

It is recommended that cutoff collars be cast around the upstream portion of the conduit in Zone 1 in order to reduce the possibility of seepage. The downstream portion of the conduit through Zones 2 and 3 should be surrounded by a minimum thickness of 1 m of pervious filter in order to prevent possible erosion along the conduit.

Settlement and horizontal elongation of the conduit can be expected as the embankment fill is constructed. The conduit must be designed to accommodate these movements. The deformation could be minimized if the conduit were placed directly on bedrock.

4.9 Concrete

A suitable source of concrete aggregate has not been identified. The alluvial deposits in the valley and high level terrace would have to be crushed, screened and washed in order to obtain suitable aggregate for concrete. The durability and soundness of these aggregates is not known.

Unless water soluble sulphate tests are undertaken on soil samples during final design it is recommended that Type 50 sulphate resistant cement be used for all concrete in contact with soil at this site. This is particularly important for the low level conduit, which is subject to an unfavourable hydraulic environment from the point of view of potential attack by sulphates.

4.10 Additional Geotechnical Investigations

If a decision is made to proceed with construction of a dam at Site 7A, the following geotechnical work is recommended:

1) Test pits and additional test holes should be drilled in the glaciolacustrine and alluvial deposits along the dam centreline, as well as upstream and downstream of the centreline. The objectives of this work are:

    - To identify the quality and quantity of granular materials for use in embankment construction,

    - to locate and test suitable sources of concrete aggregate,

    - to further delineate the orientation and inclination of potential ice-thrust features in the bedrock, and to obtain appropriate data for the development of bedrock strength parameters for stability analyses.

    - to further delineate the depth to bedrock in the valley bottom, and depth to impervious strata in the abutment areas along the centreline of the proposed cutoff, as well as to establish potential difficulties in making the excavation for the cutoff,

- to carry out insitu permeability tests in overburden soils in the abutment areas,

- to establish the depth to bedrock along the centreline of the proposed toe drain.

2) High pressure injection tests should be undertaken in the bedrock along the dam centreline and near the toe of the embankment in the areas of relatively shallow bedrock, in order to assess the stratigraphy and permeability of the bedrock at these locations.

3) Once the location and depth of the spillway has been confirmed, additional test holes and test pits should be drilled along the proposed centreline to establish groundwater table elevations, subsoil conditions and depth to bedrock, as well as potential construction difficulties.

4) Sources for clay borrow for use in construction of the dam embankment need to be located. Test pits and test holes should be drilled in potential clay borrow areas. Specifically, it is necessary to determine the following:

   - The susceptibility of the clay till to internal piping (dispersion tests are recommended),

   - the water soluble sulphate content of the clay borrow, and

   - the compaction properties of the clay borrow.

5) It is recommended that additional pneumatic piezometers be installed at selected locations in the vicinity of the damsite in order to establish current piezometric pressures in the bedrock at the site. This information is required in order to evaluate the stability of the proposed embankment.

6) A program of laboratory strength testing should be undertaken on samples of compacted clay till, on undisturbed alluvium and on undisturbed samples of bedrock core in order to establish the effective stress strength and pore pressure parameters of these materials for use in stability analyses.

7) A suitable source of rip rap for upstream slope protection should be located.

8) An earth materials balance study should be carried out in order to optimize the configuration of the dam embankment as well as to establish the most efficient sequence of construction.

9) Selective stability and settlement analyses should be undertaken in order to refine the design of the embankment.

10) Three deep seated landslides have been noted along the valley walls upstream from the dam embankment, one of which will be within the reservoir area. Detailed geotechnical investigations will be required to assess the effects of reservoir impoundment on the stability of the affected landslide. This work should include an assessment of possible wave generation by landslide activity. In addition, the failure mechanism for all three landslides should also be established, as this information will have an impact on the soil parameters used for the design of the dam embankment.

11) Detailed field checking of the valley slopes along the reservoir should be undertaken in order to identify other localized areas where the potential for instability is of concern.

12) A detailed hydrogeological assessment of the damsite and reservoir should be undertaken in order to assess the impact of the proposed reservoir on the groundwater regime. This work should include a more detailed evaluation of lateral seepage from the reservoir.

It is expected that 5 to 6 months would be required to complete the geotechnical investigations outlined above.

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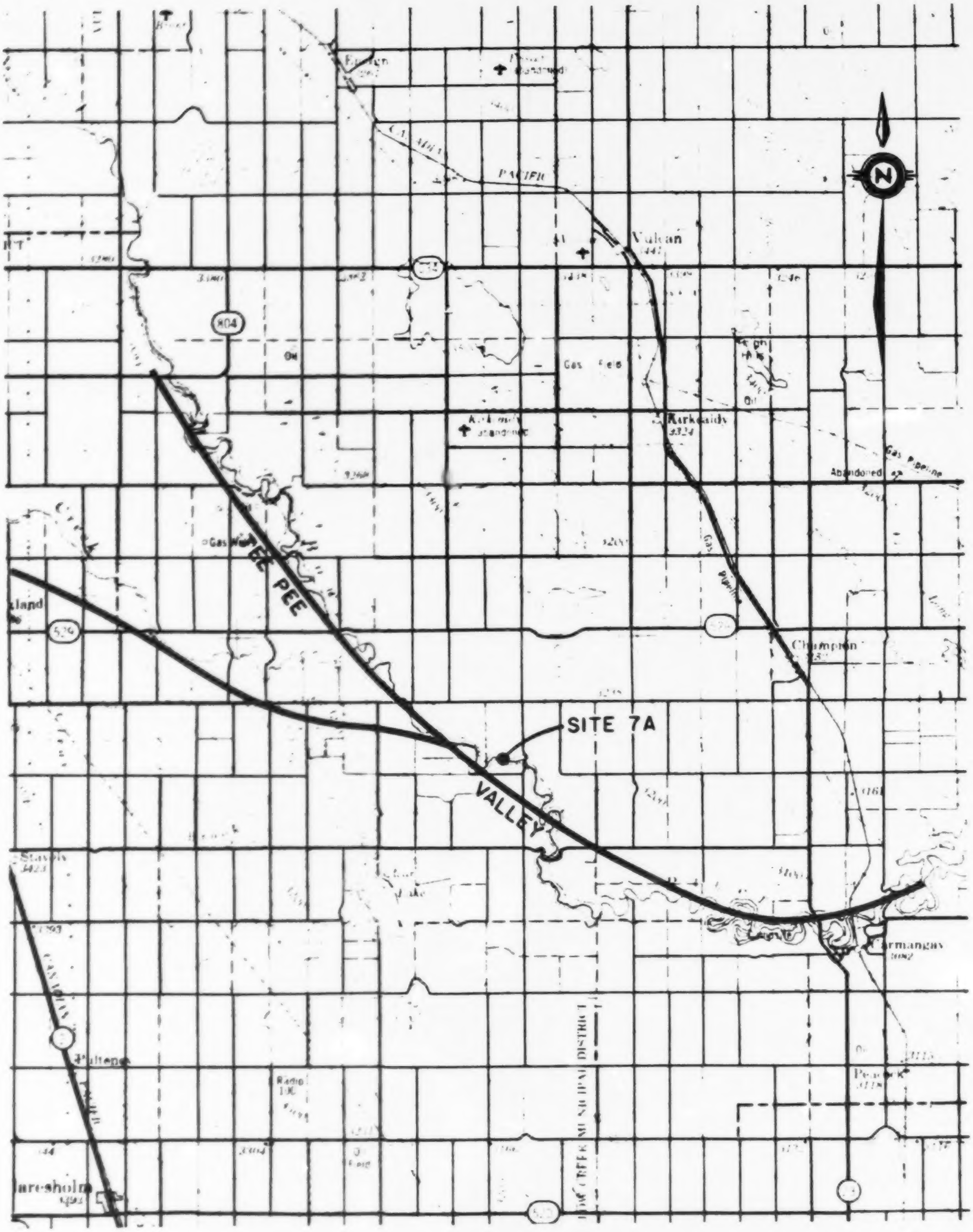
APPENDIX A

DRAWINGS

- DRAWING 1 - Site Plan
- DRAWING 2 - Test Hole Locations
- DRAWING 3 - Surficial Geology - Reservoir
- DRAWING 4 - Surficial Geology - Damsite
- DRAWING 5 - Geological Cross-Section
- DRAWING 6 - Preliminary Embankment Design 61,700 Dam3 Capacity
- DRAWING 7 - Preliminary Embankment Design 80,300 Dam3 Capacity


Vulcan
804
Gas Field
Kirkcaldy
Gas Pipeline
Abandoned
Gas Well
TEE PEE
VALLEY
529
Champion
SITE 7A
Stavely
Carmangay
Pulteney
Radio
Peacock
Claresholm
CANADIAN PACIFIC
N

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LOCATION PLAN

LITTLE BOW RIVER SITE 7A

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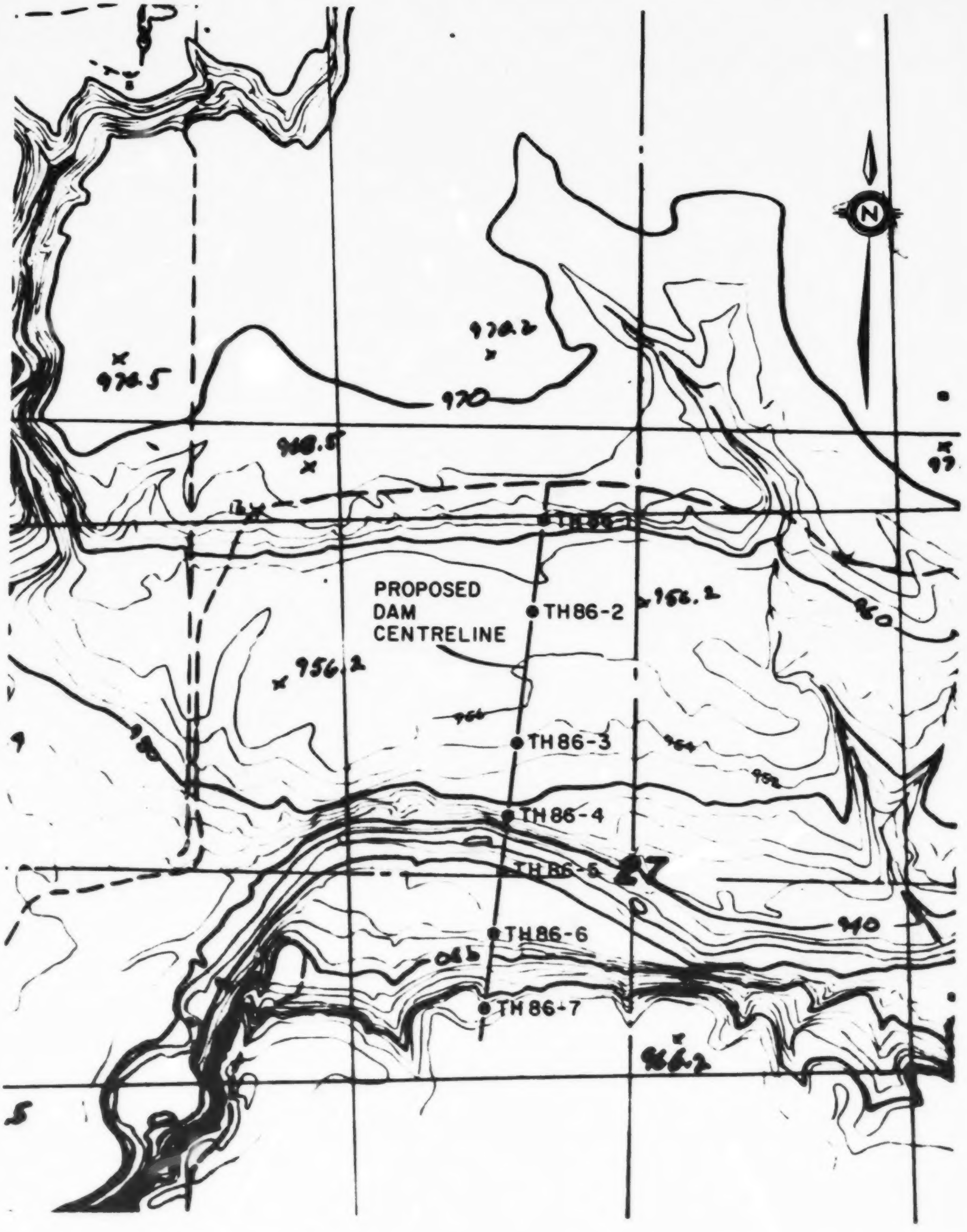

N
976.5
970.2
970
968.5
97
TH86-1
PROPOSED
DAM
CENTRELINE
TH86-2
956.2
960
956.2
956
TH86-3
954
952
950
9
TH86-4
TH86-5
27
940
TH86-6
TH86-7
966.2
5

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TEST HOLE LOCATIONS

LITTLE BOW RIVER SITE 7A

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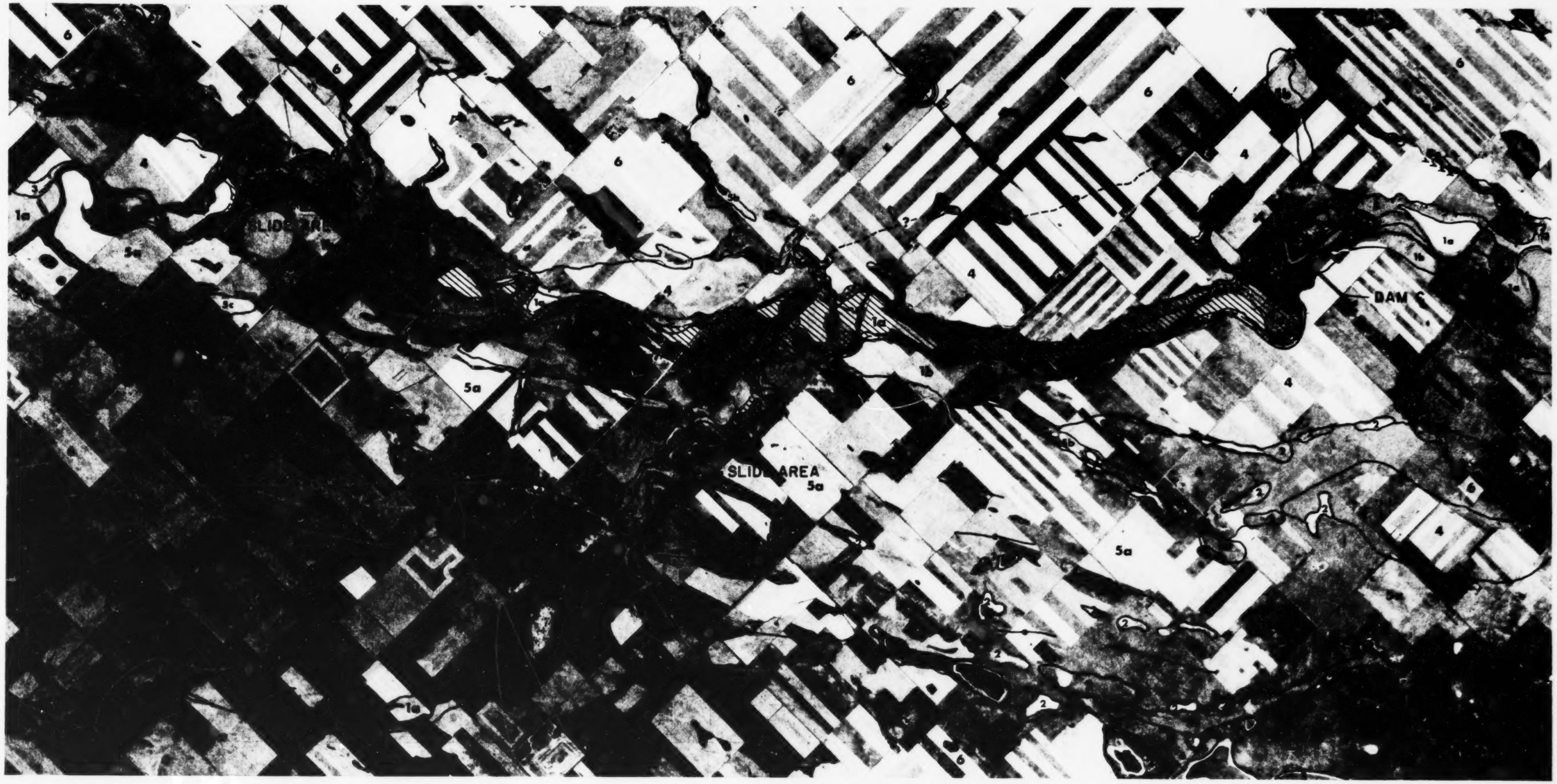
6
6
6
6
6
6
4
4
4
4
1a
1a
1a
1a
1b
1b
3
2
2
2
2
2
SLIDE AREA
SLIDE AREA
5a
5a
5a
5a
5c
DAM C
6
6

LITTL

THURBER CON

LEGEND

MAP UNIT	DESCRIPTION
1a	ALLUVIAL FLOODPLAIN AND (RECENT) TERRACE
1b	HIGH-LEVEL ALLUVIAL TERRACE
2	RECENT LAKE BASIN
3	COLLUVIAL SLOPEWASH
4	GLACIOLACUSTRINE PLAIN
5a	GLACIOFLUVIAL PLAIN
5b	GLACIOFLUVIAL ESKER
5c	GLACIOFLUVIAL KAME
6	GROUND MORAINE
∼	SURFICIAL GEOLOGY BOUNDARY
⌒⌒	ESCARPMENT
>>>>>	ESKER (SMALL)
—•—	DRUMLINOID RIDGE
▨	RESERVOIR LIMITS

W-E-R ENGINEERING LTD.

SURFICIAL GEOLOGY
86,300 DAM^3 RESERVOIR

LITTLE BOW RIVER SITE 7A

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APPROVED I. Jones
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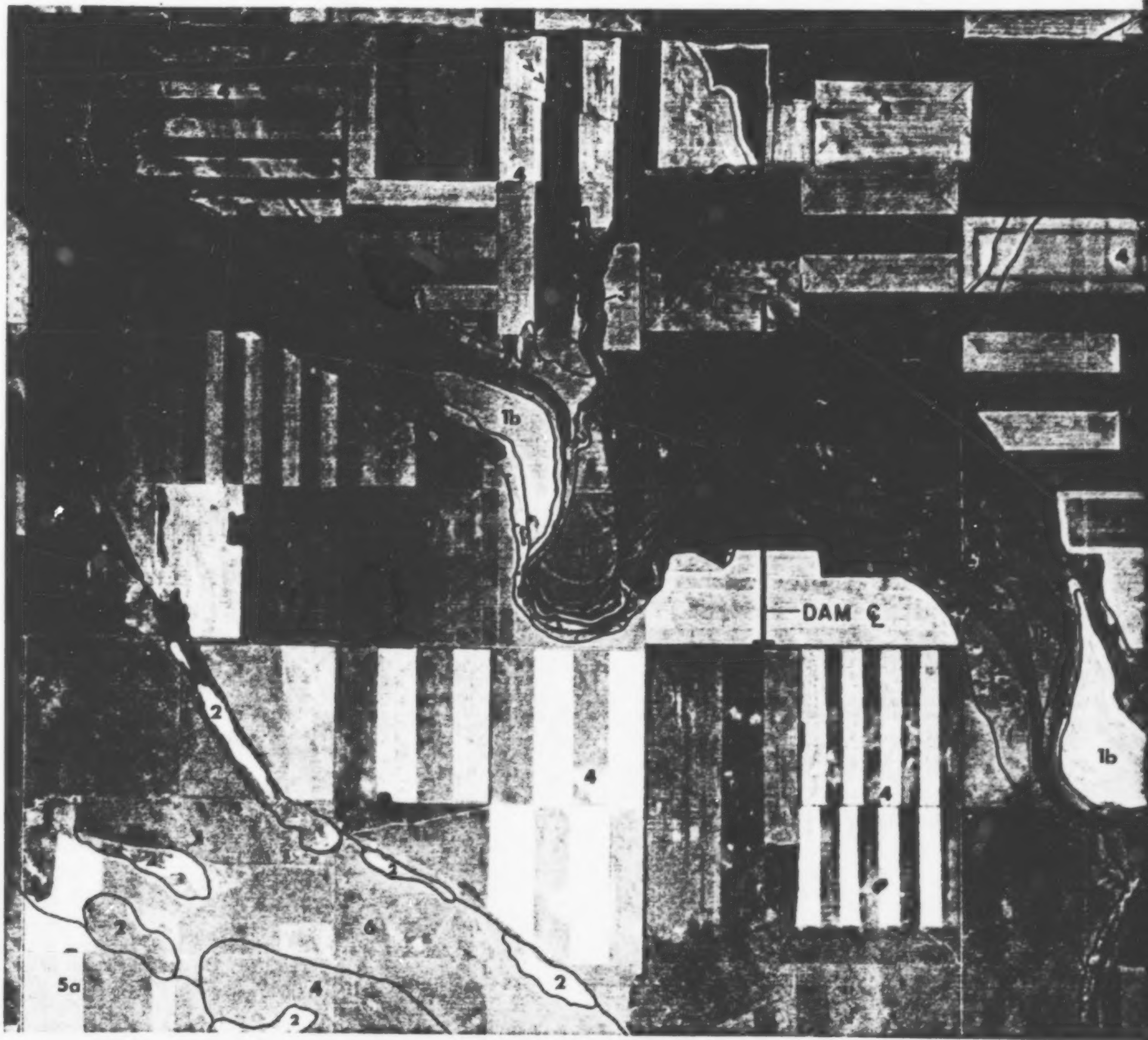
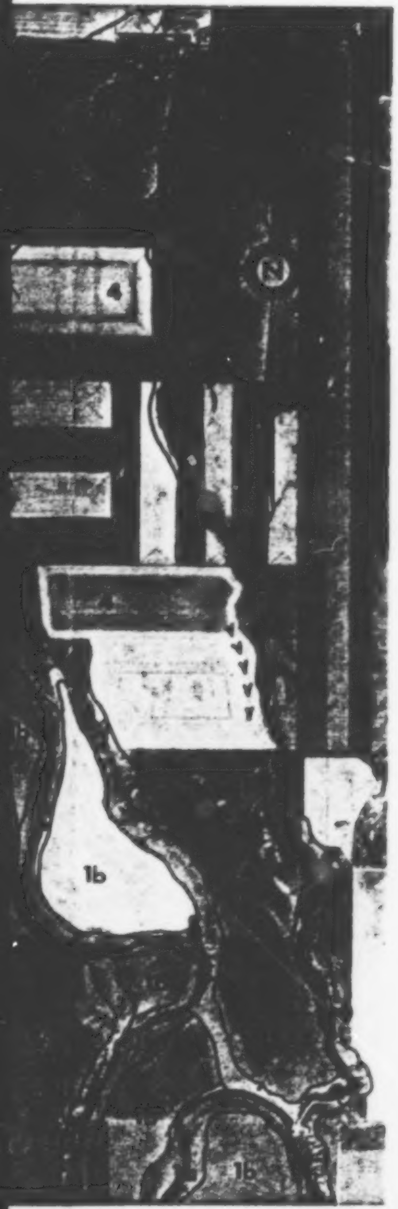

4
4
1b
DAM ℄
2
4
4
1b
2
2
2
6
5a
4
2



LEGEND

MAP UNIT	DESCRIPTION
1a	ALLUVIAL FLOODPLAIN
1b	ALLUVIAL TERRACE
1c	HIGH-LEVEL TERRACE
2	RECENT LAKE BASIN
3	COLLUVIAL SLOPEWASH
4	GLACIOLACUSTRINE PLAIN
5a	GLACIOFLUVIAL PLAIN
5b	GLACIOFLUVIAL ESKER
6	GROUND MORAINE
⁓	SURFICIAL GEOLOGY BOUNDARY
⌒	ESCARPMENT
⊖	ALLUVIAL FAN
>>>>	ESKER (SMALL)

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SURFICIAL GEOLOGY-DAMSITE

LITTLE BOW RIVER SITE 7A

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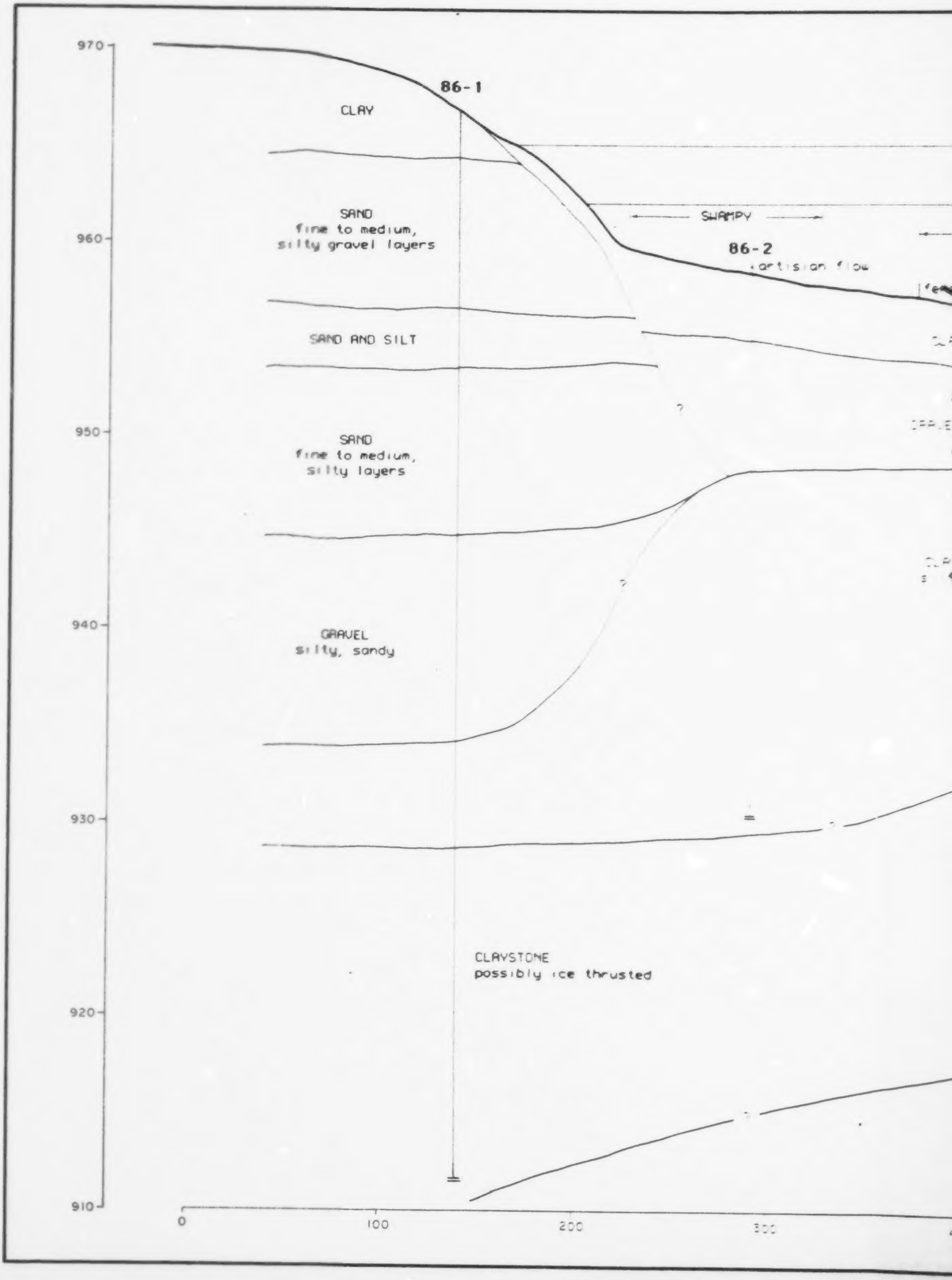
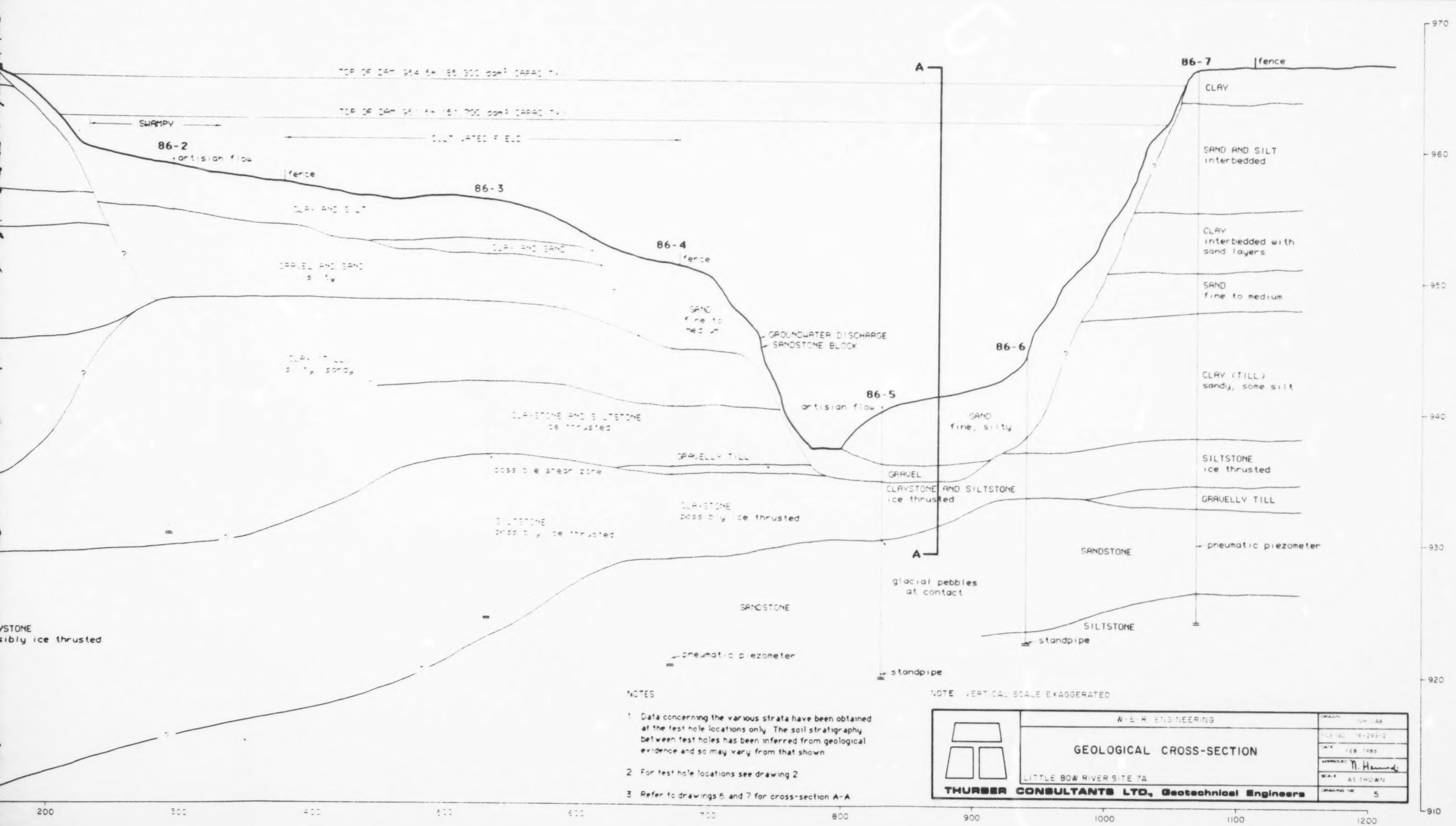

970
960
950
940
930
920
910
86-1
CLAY
SAND
fine to medium,
silty gravel layers
SWAMPY
86-2
artisian flow
SAND AND SILT
?
SAND
fine to medium,
silty layers
?
GRAVEL
silty, sandy
CLAYSTONE
possibly ice thrusted
0
100
200
300


TOP OF DAM 964.6m (85 300 dam³ CAPACITY)
TOP OF DAM 961.6m (61 700 dam³ CAPACITY)
SWAMPY
CULTIVATED FIELD
86-2
artisian flow
fence
86-3
CLAY AND SILT
CLAY AND SAND
GRAVEL AND SAND
silty
86-4
fence
SAND
fine to
medium
GROUNDWATER DISCHARGE
SANDSTONE BLOCK
CLAY (TILL)
silty, sandy
CLAYSTONE AND SILTSTONE
ice thrusted
GRAVELLY TILL
possible shear zone
CLAYSTONE
possibly ice thrusted
SILTSTONE
possibly ice thrusted
YSTONE
sibly ice thrusted
SANDSTONE
pneumatic piezometer
86-5
artisian flow
GRAVEL
CLAYSTONE AND SILTSTONE
ice thrusted
glacial pebbles
at contact
standpipe
A
A
86-6
SAND
fine, silty
standpipe
86-7
fence
CLAY
SAND AND SILT
interbedded
CLAY
interbedded with
sand layers
SAND
fine to medium
CLAY (TILL)
sandy, some silt
SILTSTONE
ice thrusted
GRAVELLY TILL
pneumatic piezometer
SANDSTONE
SILTSTONE
?
970
960
950
940
930
920
910
200
300
400
500
600
700
800
900
1000
1100
1200

NOTES

1. Data concerning the various strata have been obtained at the test hole locations only. The soil stratigraphy between test holes has been inferred from geological evidence and so may vary from that shown.
2. For test hole locations see drawing 2
3. Refer to drawings 6 and 7 for cross-section A-A

NOTE: VERTICAL SCALE EXAGGERATED

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GEOLOGICAL CROSS-SECTION

LITTLE BOW RIVER SITE 7A

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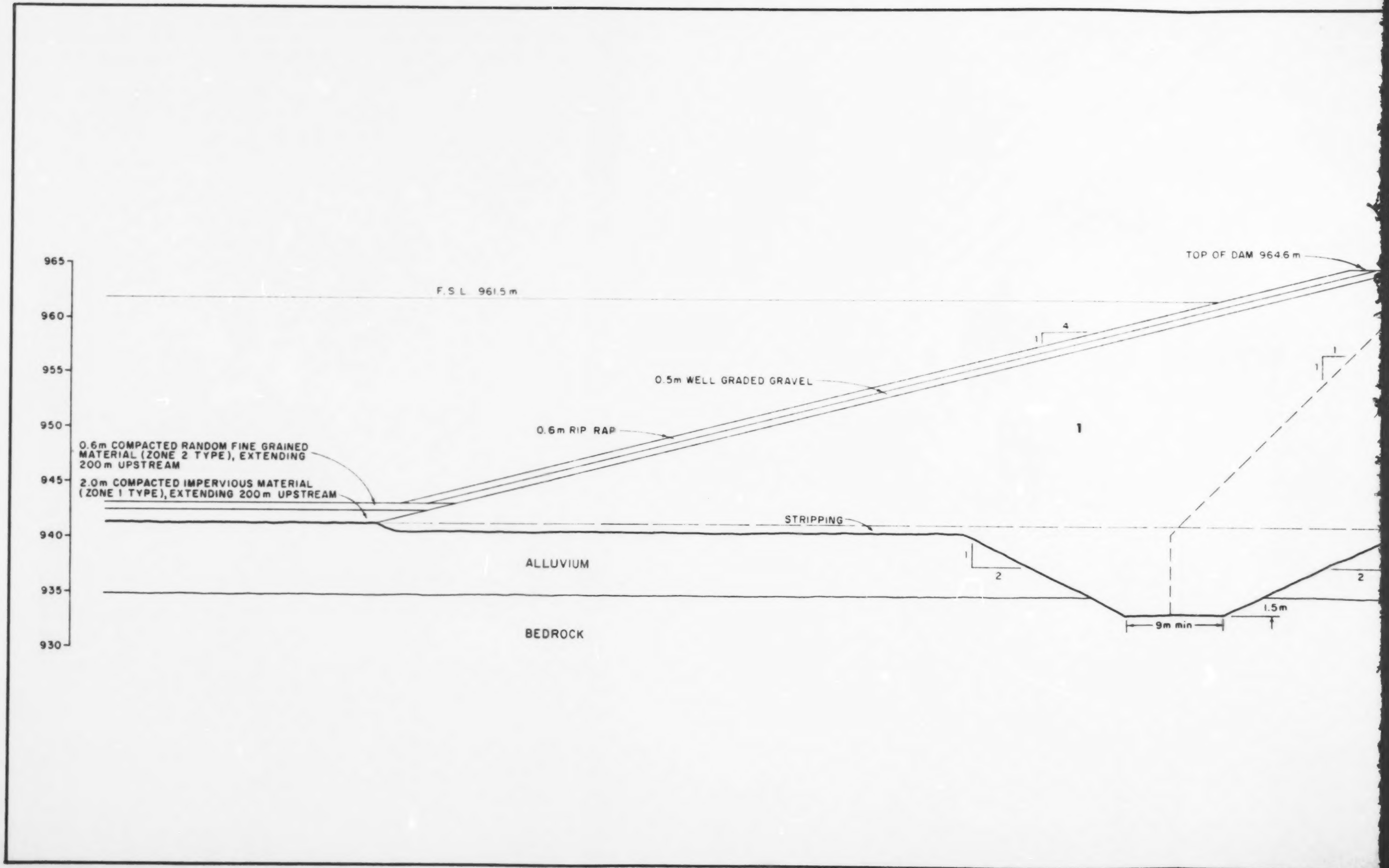
SCALE	AS SHOWN
DRAWING NO.	5


965
960
955
950
945
940
935
930
F.S.L. 961.5 m
TOP OF DAM 964.6 m
1
4
0.5m WELL GRADED GRAVEL
0.6m RIP RAP
1
0.6m COMPACTED RANDOM FINE GRAINED MATERIAL (ZONE 2 TYPE), EXTENDING 200m UPSTREAM
2.0m COMPACTED IMPERVIOUS MATERIAL (ZONE 1 TYPE), EXTENDING 200m UPSTREAM
STRIPPING
ALLUVIUM
BEDROCK
1
2
9m min
1.5m
1
1
2

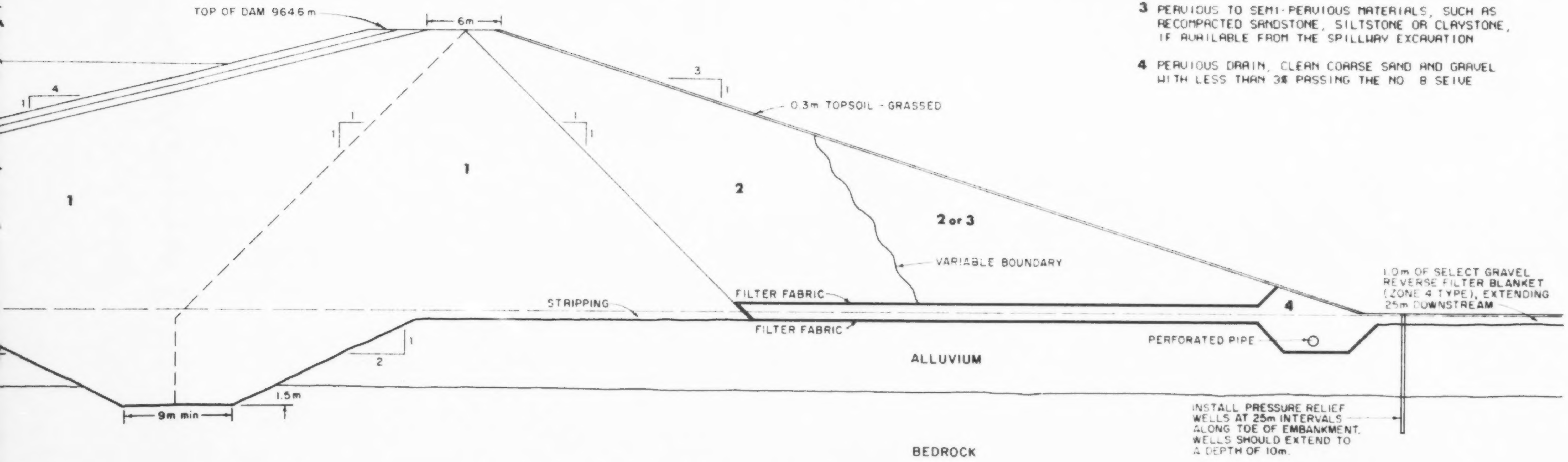
LEGEND

1 IMPERVIOUS MATERIAL, WELL COMPACTED CLAY TILL FROM UPLANDS SOURCES

2 PERVIOUS TO SEMI-PERVIOUS MATERIALS, SUCH AS RANDOM SANDS AND GRAVELS FROM CUTOFF EXCAVATION AND BORROW AREAS IN ALLUVIUM OR COARSE GRAINED GLACIOLACUSTRINE DEPOSITS

3 PERVIOUS TO SEMI-PERVIOUS MATERIALS, SUCH AS RECOMPACTED SANDSTONE, SILTSTONE OR CLAYSTONE, IF AVAILABLE FROM THE SPILLWAY EXCAVATION

4 PERVIOUS DRAIN, CLEAN COARSE SAND AND GRAVEL WITH LESS THAN 3% PASSING THE NO 8 SEIVE


TOP OF DAM 964.6 m
6m
4
1
3
1
1
1
1
1
0.3m TOPSOIL - GRASSED
1
1
2
2 or 3
VARIABLE BOUNDARY
1.0m OF SELECT GRAVEL REVERSE FILTER BLANKET (ZONE 4 TYPE), EXTENDING 25m DOWNSTREAM
FILTER FABRIC
STRIPPING
4
FILTER FABRIC
1
2
PERFORATED PIPE
ALLUVIUM
1.5m
9m min
BEDROCK

INSTALL PRESSURE RELIEF WELLS AT 25m INTERVALS ALONG TOE OF EMBANKMENT. WELLS SHOULD EXTEND TO A DEPTH OF 10m.

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PRELIMINARY EMBANKMENT DESIGN
86,300 dam^3 CAPACITY

LITTLE BOW RIVER SITE 7A

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NH/JAB
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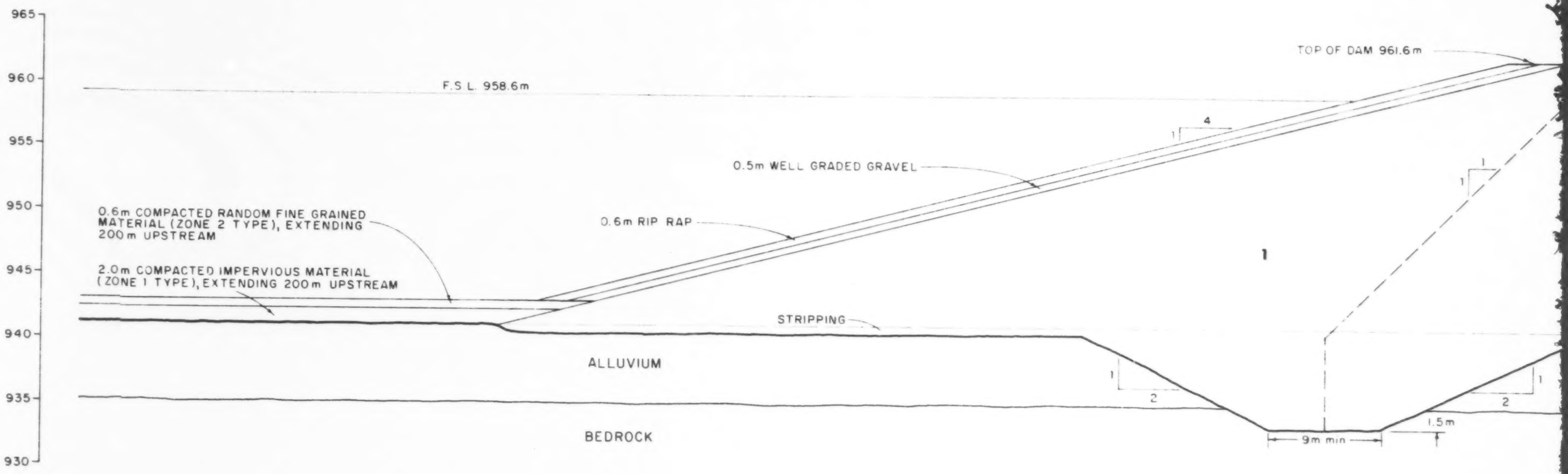
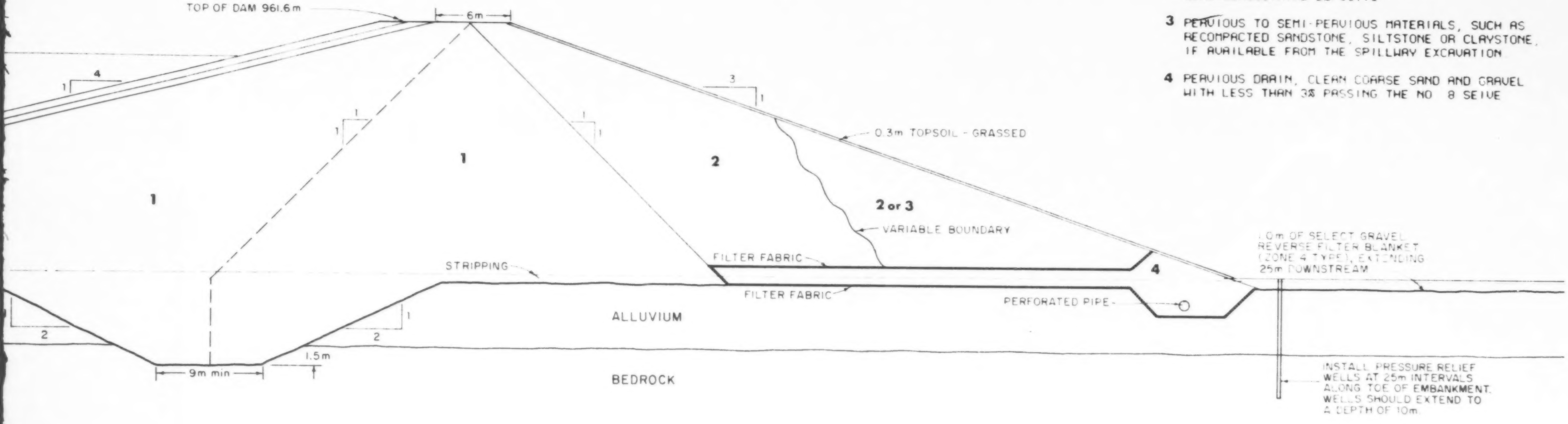
6


F.S.L. 958.6m
TOP OF DAM 961.6m
0.5m WELL GRADED GRAVEL
0.6m RIP RAP
0.6m COMPACTED RANDOM FINE GRAINED MATERIAL (ZONE 2 TYPE), EXTENDING 200m UPSTREAM
2.0m COMPACTED IMPERVIOUS MATERIAL (ZONE 1 TYPE), EXTENDING 200m UPSTREAM
STRIPPING
ALLUVIUM
BEDROCK
1.5m
9m min


TOP OF DAM 961.6m
6m
4
1
3
1
1
1
1
1
0.3m TOPSOIL - GRASSED
1
1
2
2 or 3
VARIABLE BOUNDARY
FILTER FABRIC
STRIPPING
FILTER FABRIC
4
1.0m OF SELECT GRAVEL
REVERSE FILTER BLANKET
(ZONE 4 TYPE), EXTENDING
25m DOWNSTREAM
PERFORATED PIPE
ALLUVIUM
2
2
1
1.5m
9m min
BEDROCK
INSTALL PRESSURE RELIEF
WELLS AT 25m INTERVALS
ALONG TOE OF EMBANKMENT.
WELLS SHOULD EXTEND TO
A DEPTH OF 10m.

LEGEND

1 IMPERVIOUS MATERIAL, WELL COMPACTED CLAY TILL FROM UPLANDS SOURCES

2 PERVIOUS TO SEMI-PERVIOUS MATERIALS, SUCH AS RANDOM SANDS AND GRAVELS FROM CUTOFF EXCAVATION AND BORROW AREAS IN ALLUVIUM OR COARSE GRAINED GLACIOLACUSTRINE DEPOSITS

3 PERVIOUS TO SEMI-PERVIOUS MATERIALS, SUCH AS RECOMPACTED SANDSTONE, SILTSTONE OR CLAYSTONE, IF AVAILABLE FROM THE SPILLWAY EXCAVATION

4 PERVIOUS DRAIN, CLEAN COARSE SAND AND GRAVEL WITH LESS THAN 3% PASSING THE NO. 8 SEIVE

W-E-R ENGINEERING LTD

PRELIMINARY EMBANKMENT DESIGN
61,700 dam^3 CAPACITY

LITTLE BOW RIVER SITE 7A

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FILE NO. 19-293-2
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APPROVED
SCALE 1:300
DRAWING No 7

APPENDIX B

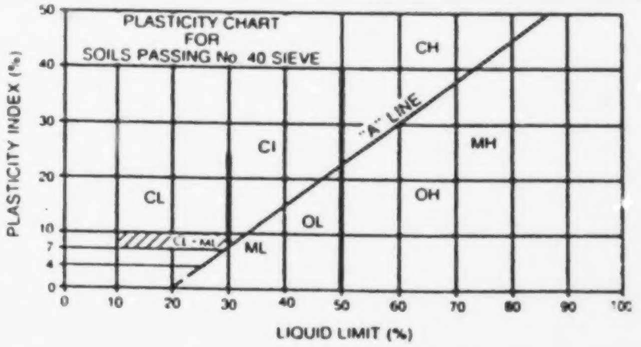
TEST HOLE LOGS

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN No 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW	▩	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 4$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP	○	POORLY GRADED GRAVELS, AND GRAVEL SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM	▥	SILTY GRAVELS, GRAVEL SAND SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			GC	▧	CLAYEY GRAVELS, GRAVEL SAND CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN No 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW	⁙	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 6$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP	░	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM	▥	SILTY SANDS, SAND SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			SC	▨	CLAYEY SANDS, SAND CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	▥	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH	▯	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL	▨	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI	▨	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH	▨	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL	▥	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH	▨	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt	≋	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	

SPECIAL SYMBOLS

▧	BEDROCK (UNDIFFERENTIATED)	▩	OVERBURDEN (UNDIFFERENTIATED)
░	SANDSTONE	░	SILTSTONE
☰	SHALE	☰	CLAYSTONE
▦	LIMESTONE	☐	
⁘	CONGLOMERATE	☐	
■	COAL	☐	



1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%

THURBER CONSULTANTS LTD.

Geotechnical Engineers

CALGARY EDMONTON VANCOUVER VICTORIA

SYMBOLS AND TERMS USED ON TEST HOLE LOGS

1. VISUAL TEXTURAL CLASSIFICATION OF MINERAL SOILS

CLASSIFICATION	APPARENT PARTICLE SIZE
Boulders	Greater than 200mm
Cobbles	75mm to 200mm
Gravel	5mm to 75mm
Sand	Not visible to 5mm
Silt	Non-Plastic particles, not visible to the naked eye
Clay	Plastic particles, not visible to the naked eye

2. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	APPROXIMATE UNDRAINED SHEAR STRENGTH
Very Soft	Less than 10kPa
Soft	10 - 25kPa
Firm	25 - 50kPa
Stiff	50 - 100kPa
Very Stiff	100 - 200kPa
Hard	200 - 300kPa
Very Hard	Greater than 300kPa

Modified from National Building Code

3. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	STANDARD PENETRATION TEST (Number of Blows per 300mm)
Very Loose	0 - 4
Loose	4 - 10
Compact	10 - 30
Dense	30 - 50
Very Dense	Over 50

Modified from National Building Code

4. LEGEND FOR TEST HOLE LOGS

○	Water content (% by weight) as determined on disturbed samples.
●	Water content (% by weight) as determined on undisturbed samples.
☐	Disturbed bag or split spoon sample.
■	Undisturbed Shelby Tube sample or core from VTM core barrel.
☒	No recovery
▨	Number of blows per 300mm for STANDARD PENETRATION TEST.
C_u	Undrained Shear Strength determined by unconfined compression test.
C_{vane}	Shear Strength determined by pocket vane.
C_{pen}	Shear Strength determined by pocket penetrometer.
▼	Water Level.

THURBER

SYMBOLS AND TERMS USED ON TEST HOLE CORING LOGS

1. Classification of Sedimentary Rocks

Claystone Siltstone	As for soils, classification is based upon Plasticity Chart

Sandstone	Grain Size Range
Fine Grained	0.06 to 0.2 mm
Medium Grained	0.2 to 0.6 mm
Coarse Grained	0.6 to 2 mm

2. Terms Describing Strength

Descriptive Term (Geological Society of London)	Approximate Uniaxial Compressive Strength
Very Weak	600 - 1250 kPa
Weak	1250 - 5000 kPa
Moderately Weak	5000 - 12500 kPa
Moderately Strong	12500 - 50000 kPa
Strong	50000 - 100000 kPa
Very Strong	100000 - 200000 kPa
Extremely Strong	Greater than 200000 kPa

3. Terms Describing Weathering/Alteration

Fresh	No visible means of weathering
Fresh Jointed	Weathering limited to major discontinuity surfaces
Slightly Weathered	Penetrative weathering on discontinuity surfaces, sight weathering of rock material
Moderately Weathered	Weathering extends throughout rock mass; rock not friable
Highly Weathered	As above; rock partially friable
Completely Weathered	Rock decomposed and in friable condition; rock texture and structure preserved

4. Legend for Test Hole Coring Logs

Rec'y.	Recovery: the total length of all material recovered in a core run expressed as a percentage of that core run length.
RQD	Rock Quality Designation: the total length of pieces of core 10 cm or more in a core run expressed as a percentage of that core run length.

RQD	Rock Quality
0-25%	Very Poor
25-50%	Poor
50-75%	Fair
75-90%	Good
90-100%	Excellent

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

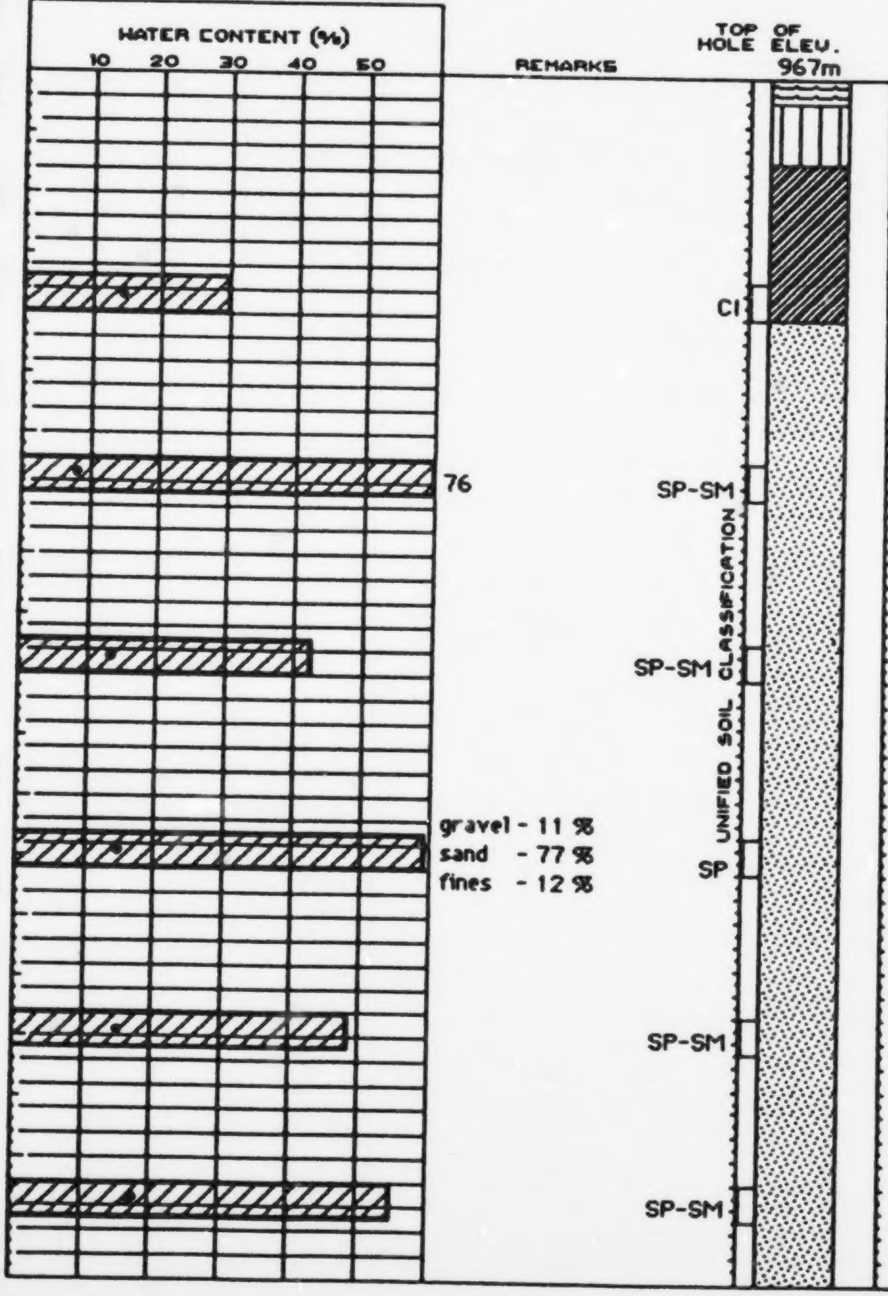
TEST HOLE NO.
86-1
Sheet 1 of 6

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 7/8, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES: DISTURBED	☐	WATER CONTENT	•
SAMPLES: UNDISTURBED	■	WATER LEVEL	⊻
SAMPLES: NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P



LOG (SCALE AS SHOWN) — DEPTH (metres)

TOPSOIL

SILT, clayey, pebbles and occasional cobbles

CLAY, silty,
medium plastic,
pockets of fine uniform sand,
frequent rust spots

1

2

SAND
medium to fine grained,
reddish brown,
coal specks,
occasional pebbles

3

4

medium grained,
uniform

5

6

fine to medium,
interbedded with thin
silty gravel layers

7

medium grained,
uniform, occasional small
sandstone inclusions

8

9

medium grained, interbedded
with silty gravel layers,
occasional streaky black
organic inclusions

10

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-1
Sheet 2 of 6

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.

PROJECT Little Bow River, Site 7A

DATE January 7/8, 1986

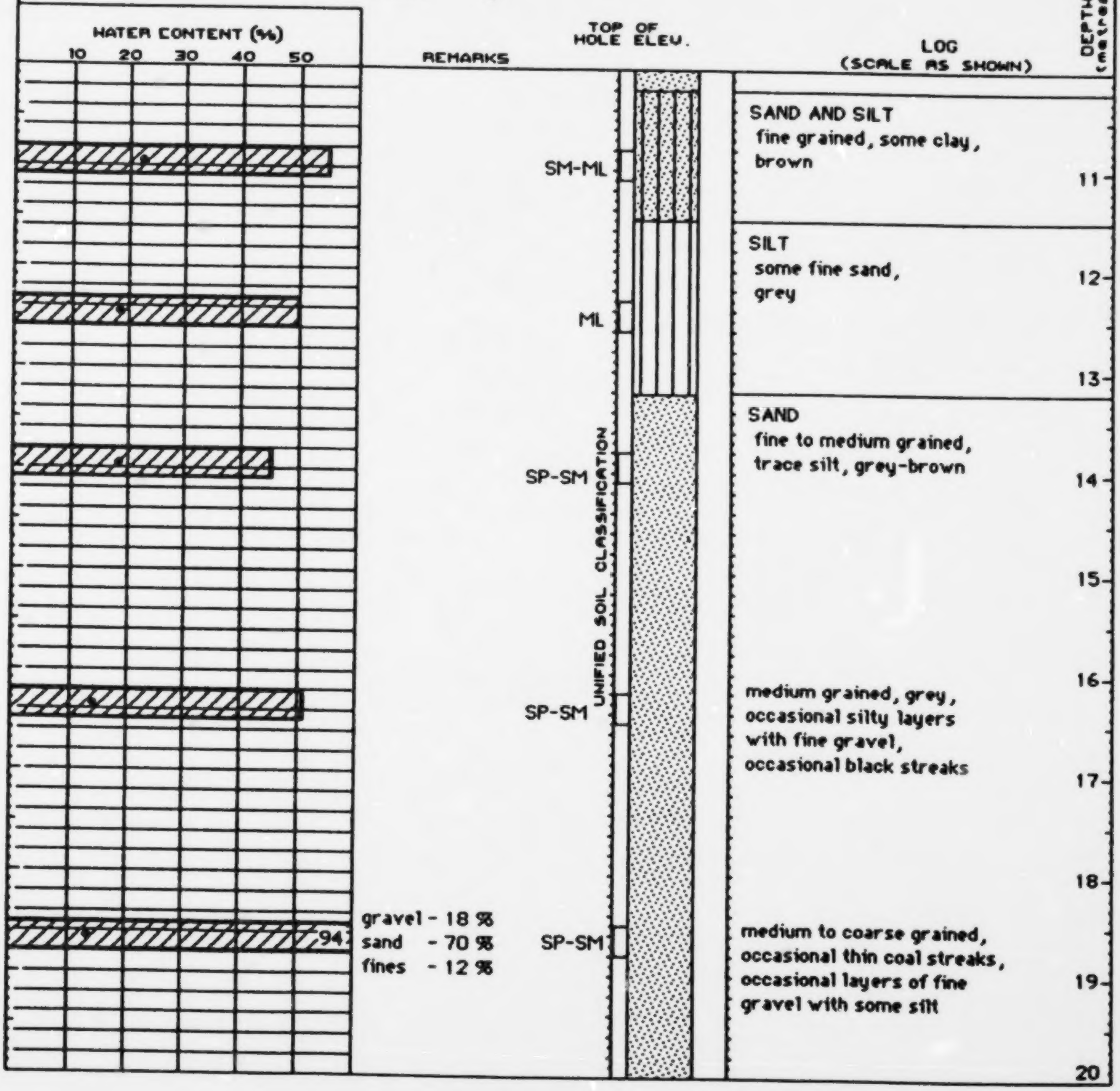
METHOD Mayhew 1000, wet rotary

DRILLING CO. SDS Drilling

INSPECTOR R. Hunt

LEGEND

SAMPLES			
DISTURBED	☐	WATER CONTENT	●
UNDISTURBED	■	WATER LEVEL	▽
NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P



gravel - 18 %
sand - 70 %
fines - 12 %

SAND AND SILT
fine grained, some clay, brown

SILT
some fine sand, grey

SAND
fine to medium grained, trace silt, grey-brown

medium grained, grey, occasional silty layers with fine gravel, occasional black streaks

medium to coarse grained, occasional thin coal streaks, occasional layers of fine gravel with some silt

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

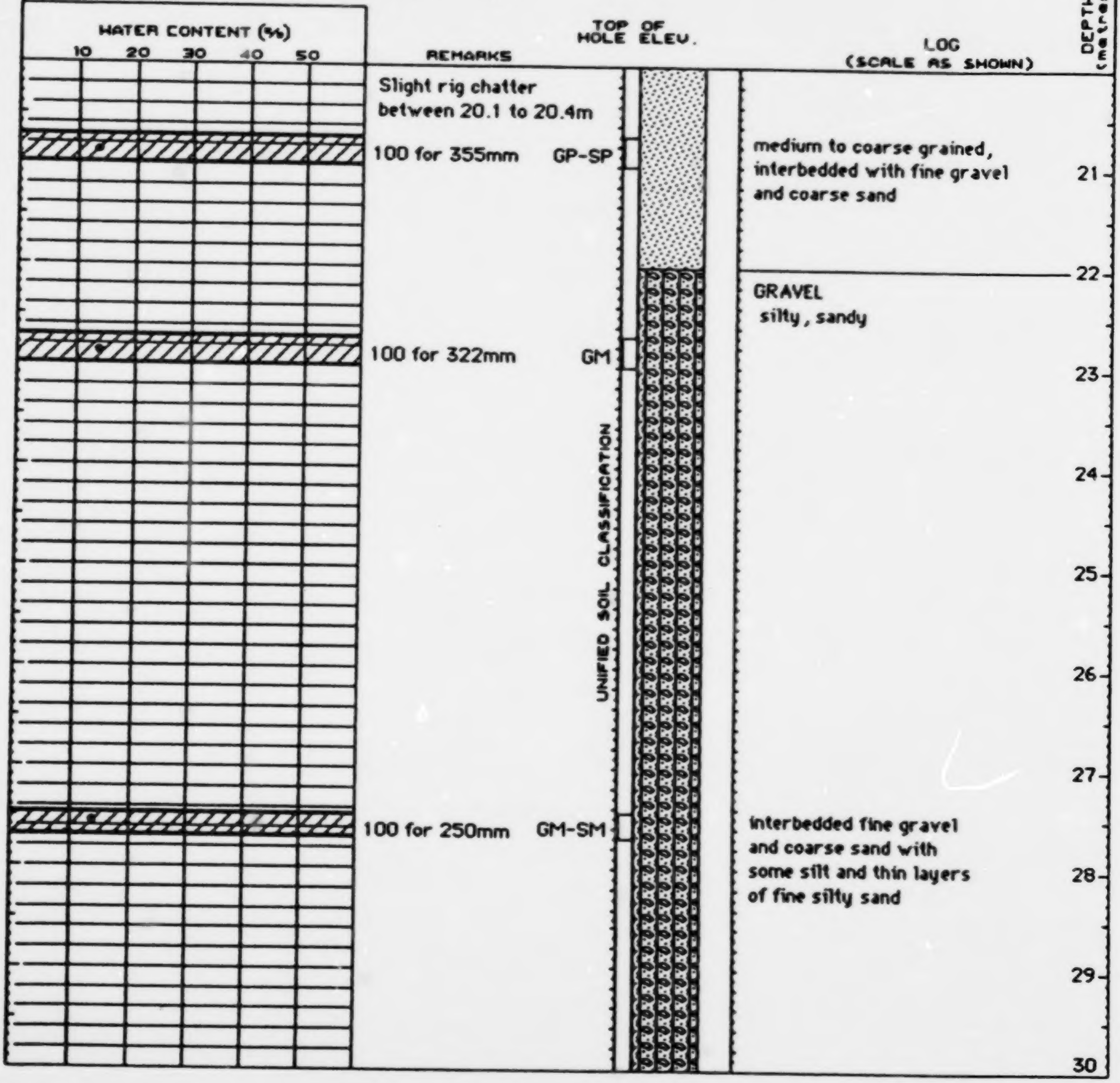
TEST HOLE NO.
86-1
Sheet 3 of 6

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 7/8, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES: DISTURBED	☐	WATER CONTENT	•
SAMPLES: UNDISTURBED	■	WATER LEVEL	▼
SAMPLES: NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P


WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV.
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
21
22
23
24
25
26
27
28
29
30

Slight rig chatter between 20.1 to 20.4m

100 for 355mm — GP-SP

medium to coarse grained, interbedded with fine gravel and coarse sand

GRAVEL
silty, sandy

100 for 322mm — GM

100 for 250mm — GM-SM

interbedded fine gravel and coarse sand with some silt and thin layers of fine silty sand

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-1
Sheet 4 of 6

LOCATION See Drawing No. 2

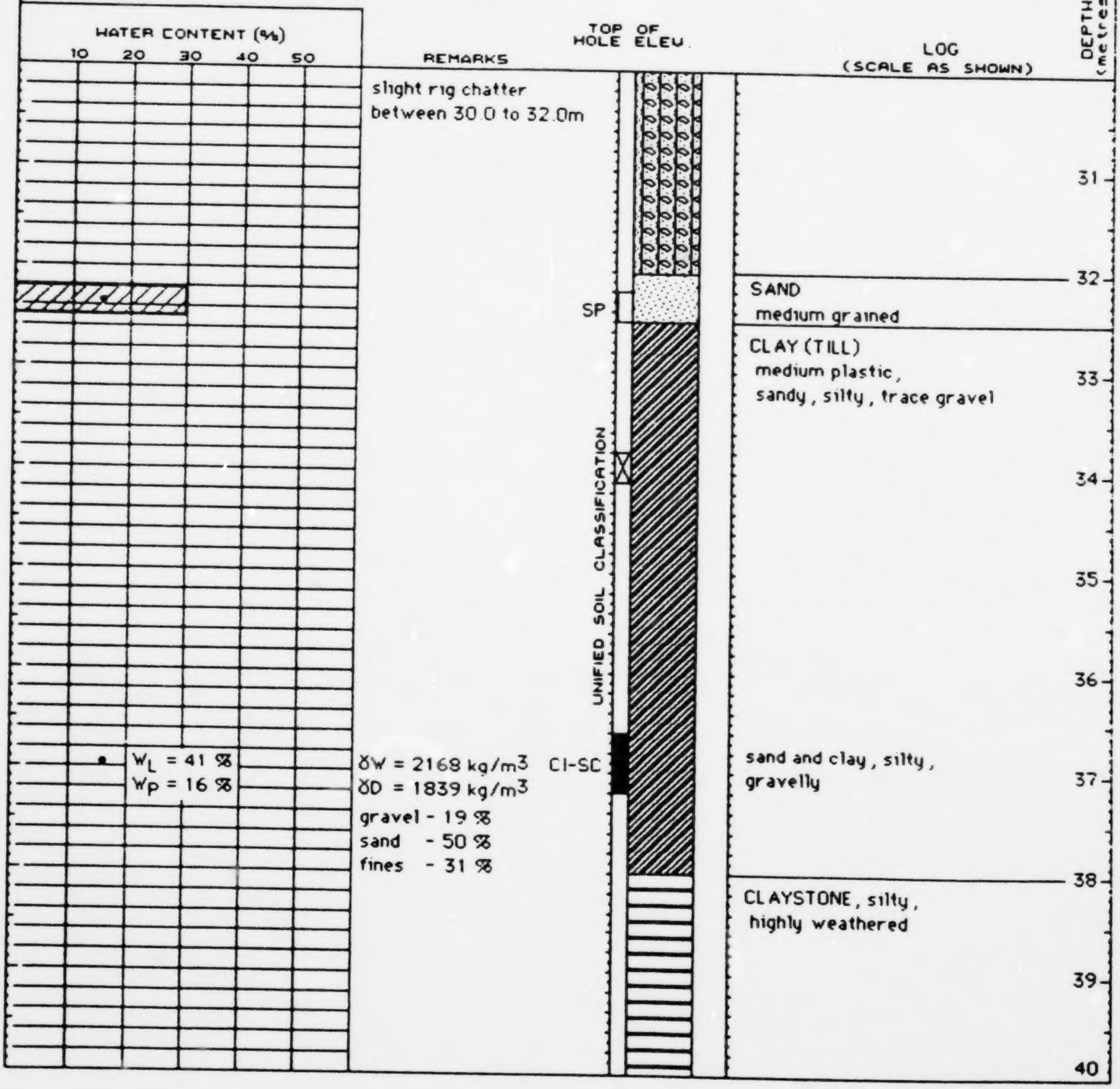
CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A

DATE January 7/8, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P



WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV.
LOG (SCALE AS SHOWN)
DEPTH (metres)
UNIFIED SOIL CLASSIFICATION
SP
CI-SC
31
32
33
34
35
36
37
38
39
40

W_L = 41 %
W_P = 16 %

slight rig chatter between 30.0 to 32.0m

γW = 2168 kg/m^3
γD = 1839 kg/m^3
gravel - 19 %
sand - 50 %
fines - 31 %

SAND
medium grained

CLAY (TILL)
medium plastic,
sandy, silty, trace gravel

sand and clay, silty,
gravelly

CLAYSTONE, silty,
highly weathered

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-1 Sheet 5 of 6

LOCATION See Drawing No 2

CLIENT W-E-R Engineering Ltd

PROJECT Little Bow River, Site 7A

DATE January 7/8, 1986

METHOD Mayhew 1000, wet rotary

DRILLING CO. SDS Drilling

INSPECTOR R. Hunt

LEGEND

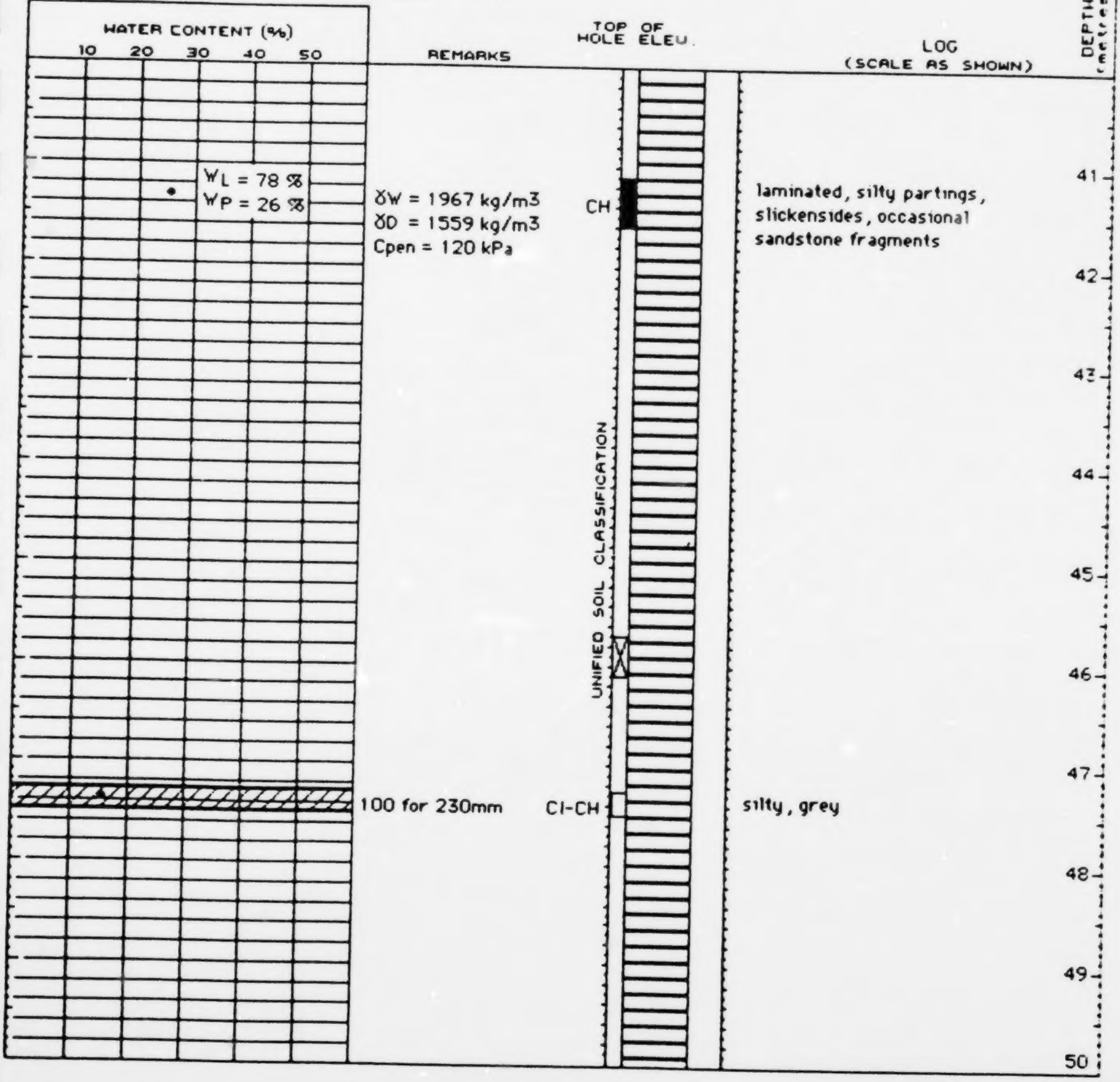
SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •

WATER LEVEL ⊻

LIQUID LIMIT W_L

PLASTIC LIMIT W_P



W_L = 78 %
W_P = 26 %

γW = 1967 kg/m3
γD = 1559 kg/m3
Cpen = 120 kPa

CH laminated, silty partings, slickensides, occasional sandstone fragments

100 for 230mm

CI-CH silty, grey

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-1
Sheet 6 of 6

LOCATION See Drawing No. 2

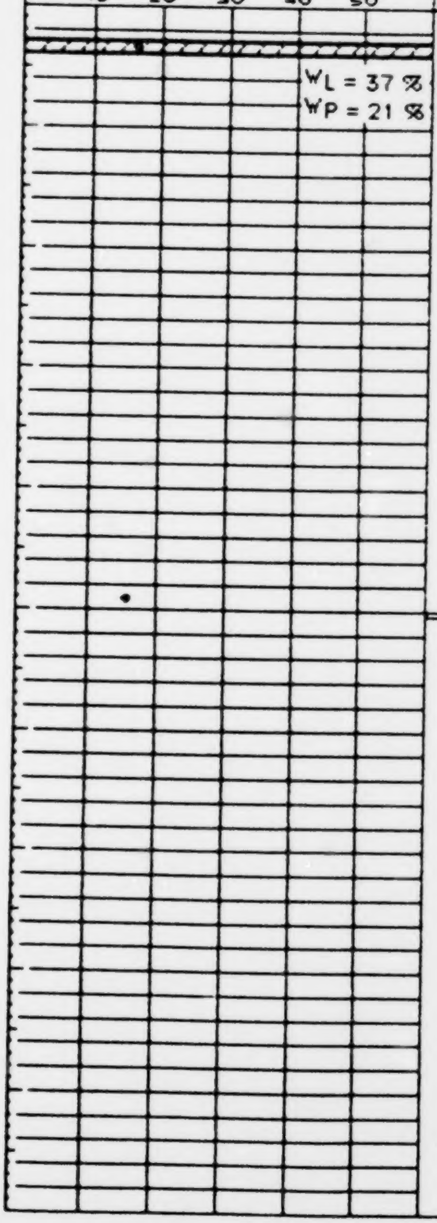
CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 7/8, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

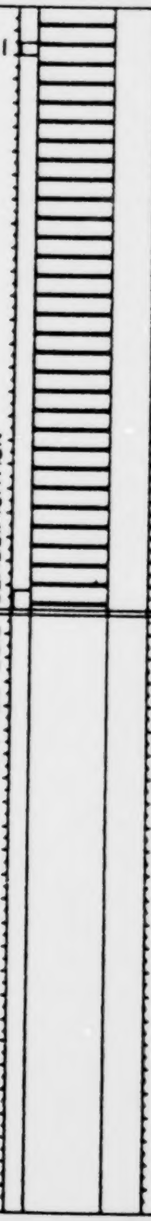
LEGEND

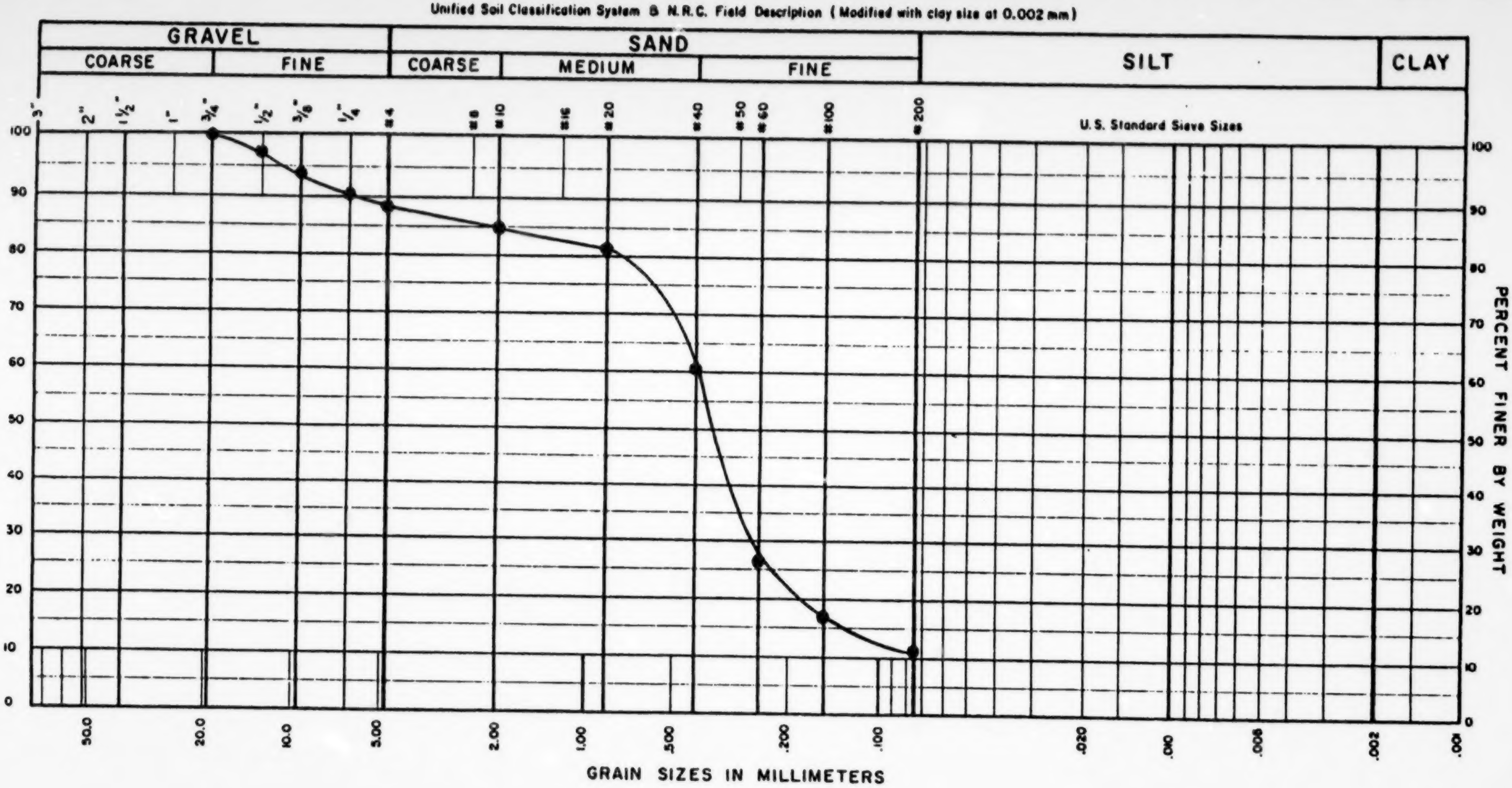
SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT ●
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P

WATER CONTENT (%)	REMARKS	TOP OF HOLE ELEV	LOG (SCALE AS SHOWN)	DEPTH (metres)
$W_L = 37\%$ $W_P = 21\%$	68 for 75mm bouncing	CI	fissured	
				51
				52
				53
				54
		CI		55
			Bottom of hole at target depth of 55.0m. Hole backfilled with cemet grout and drill cuttings.	
				56
				57
				58
				59
				60







Nat. Water Content	13.7%
Liquid Limit	
Plastic Limit	
Plastic Index	

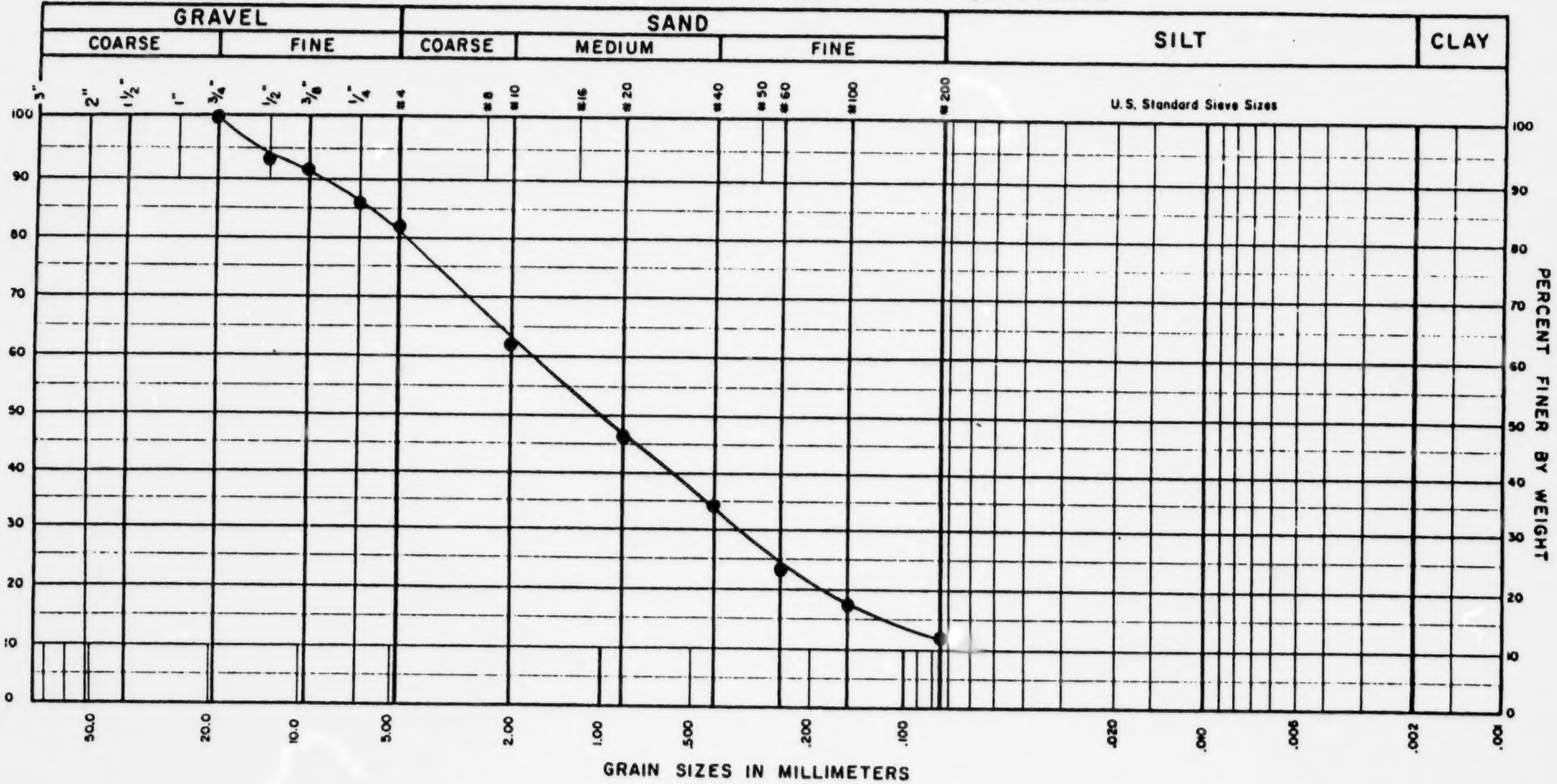
	%
Clay	12
Silt	
Sand	77
Gravel	11

Classification SAND, fine to medium, some silt, some fine gravel, SP

THURBER CONSULTANTS LTD., Geotechnical Engineers

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-1, 6.5 m
TEST DATE	FILE Nº 19-293-2

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			12.9%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay			%
Silt			12
Sand			70
Gravel			18

Classification SAND, medium to coarse, some silt and gravel, SP-SM

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-1, 18.6 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO.
86-2
Sheet 1 of 3

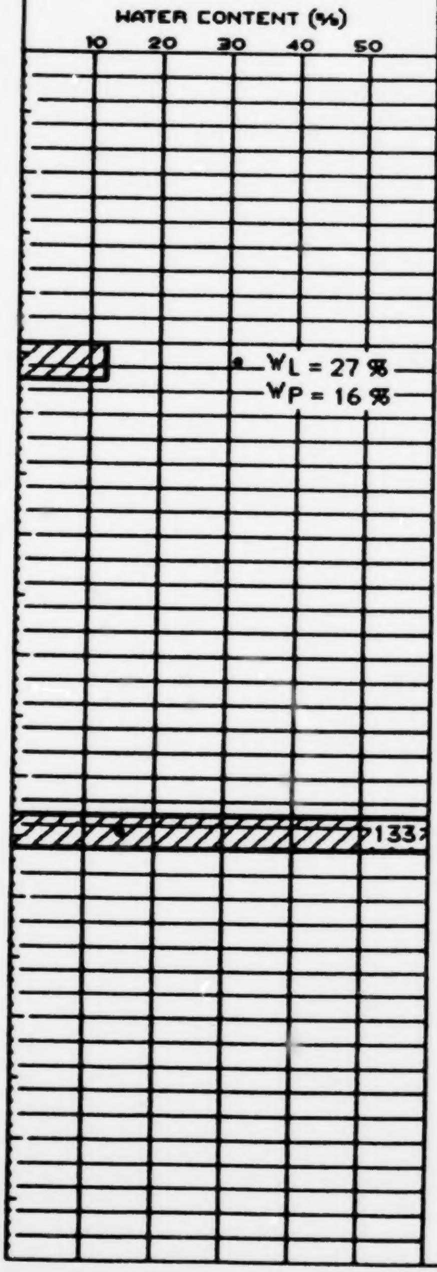
LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 14/15, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES			
DISTURBED	☐	WATER CONTENT	•
UNDISTURBED	■	WATER LEVEL	▼
NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P

WATER CONTENT (%)



REMARKS

gravel - 0 %
sand - 17 %
fines - 83 %

Rig chatter at 3.8m

Start of water flow from hole at 5.4m

Heavy rig chatter at 5.5m

gravel - 40 %
sand - 47 %
fines - 13 %

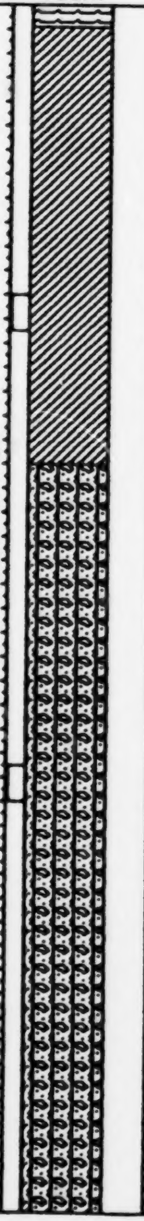
Hole caving at 9 to 10m depth. Casing set to 12.2m.

UNIFIED SOIL CLASSIFICATION

CL

GM-SM

TOP OF HOLE ELEV. 958m



LOG (SCALE AS SHOWN)

DEPTH (metres)

TOPSOIL

CLAY
low plastic,
grey-brown, mottled,
occasional rootlets and
partly decayed organics

GRAVEL
sandy, silty,
trace clay

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO.
86-2
Sheet 2 of 3

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.

PROJECT Little Bow River, Site 7A

DATE January 14/15, 1986

METHOD Mayhew 1000, wet rotary

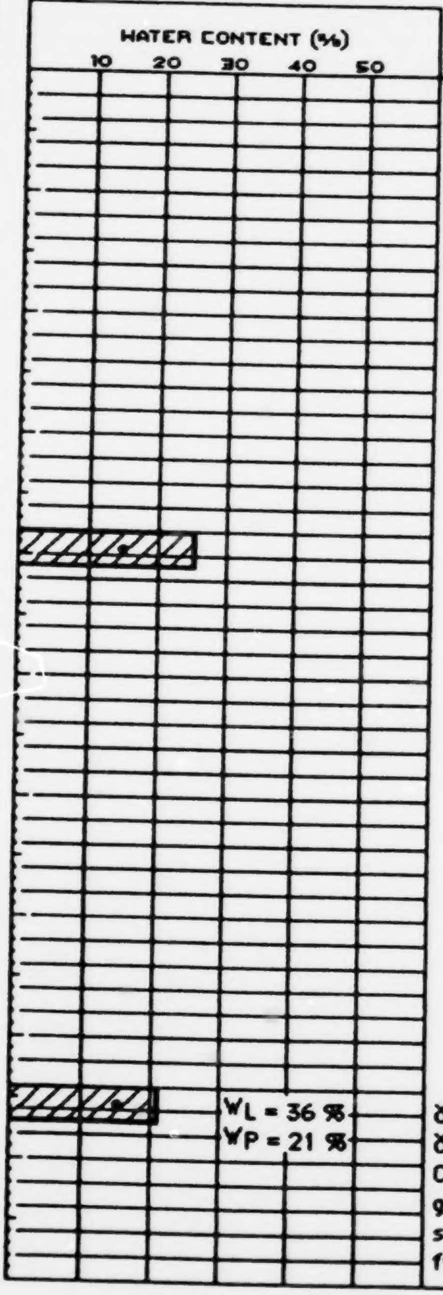
DRILLING CO. SDS Drilling

INSPECTOR R. Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P



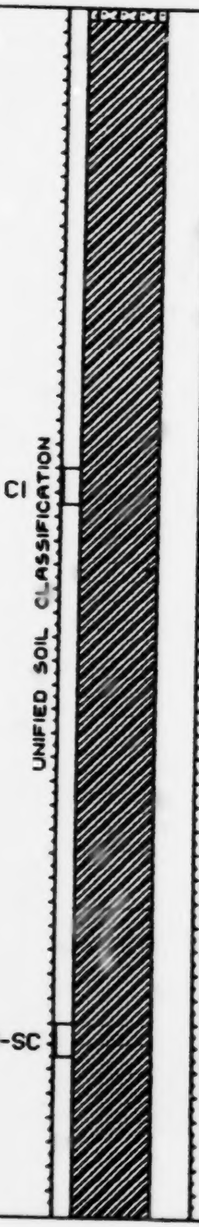
W_L = 36 %
W_P = 21 %

REMARKS

Rig chatter at 15.4m

γW = 2122 kg/m3
γD = 1821 kg/m3
Cpen = 120 kPa
gravel - 0 %
sand - 50 %
fines - 50 %

TOP OF HOLE ELEV.



LOG (SCALE AS SHOWN)

CLAY (TILL)
medium to low plastic, some gravel

dark grey, frequent small claystone inclusions

trace coarse sand and pebbles, small pockets of medium sand

DEPTH (metres)
11
12
13
14
15
16
17
18
19
20

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

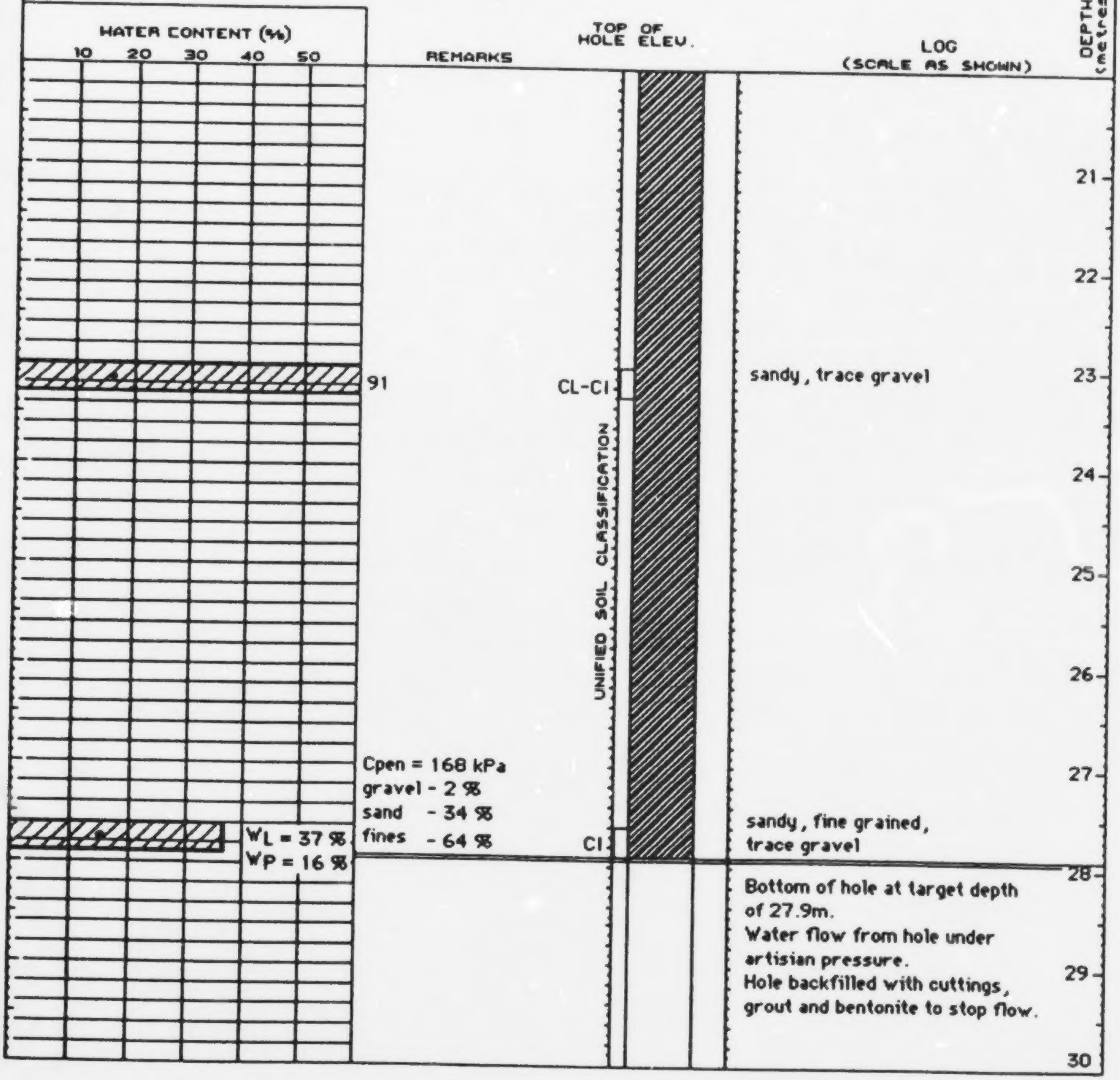
TEST HOLE NO.
86-2
Sheet 3 of 3

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 14/15, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES			
DISTURBED	☐	WATER CONTENT	•
UNDISTURBED	■	WATER LEVEL	▽
NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P



WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV.
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
21
22
23
24
25
26
27
28
29
30

91

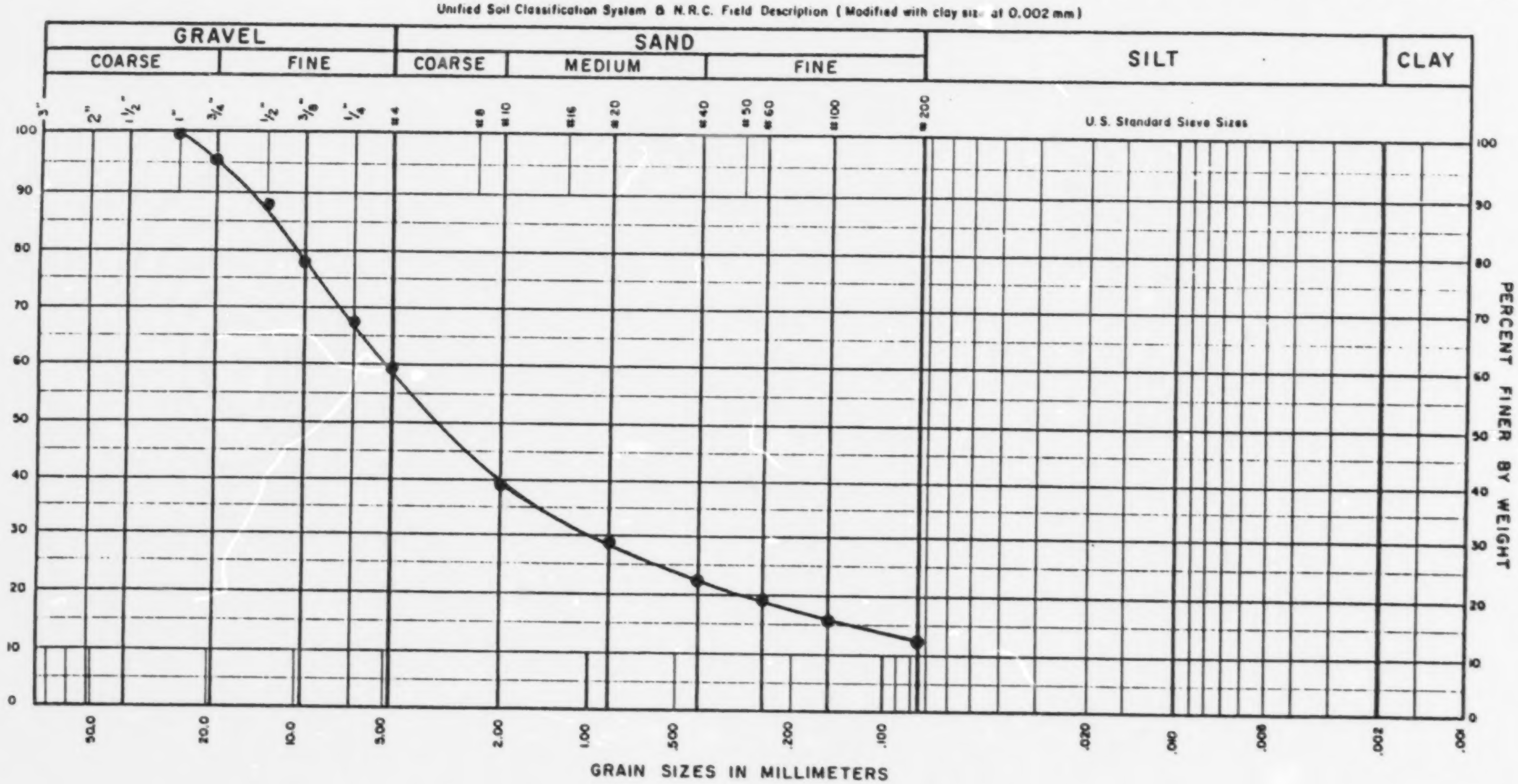
CL-CI sandy, trace gravel

Cpen = 168 kPa
gravel - 2 %
sand - 34 %
fines - 64 %

W_L = 37 %
W_P = 16 %

CI sandy, fine grained, trace gravel

Bottom of hole at target depth of 27.9m.
Water flow from hole under artisian pressure.
Hole backfilled with cuttings, grout and bentonite to stop flow.



Nat. Water Content			15.0%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay			} %
Silt			}13
Sand			47
Gravel			40

Classification GRAVEL and SAND, coarse to fine, some silt, GM-SM

THURBER CONSULTANTS LTD., Geotechnical Engineers

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-2, 6.4 m
TEST DATE	FILE Nº 19-293-2

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO.
86-3
Sheet 1 of 5

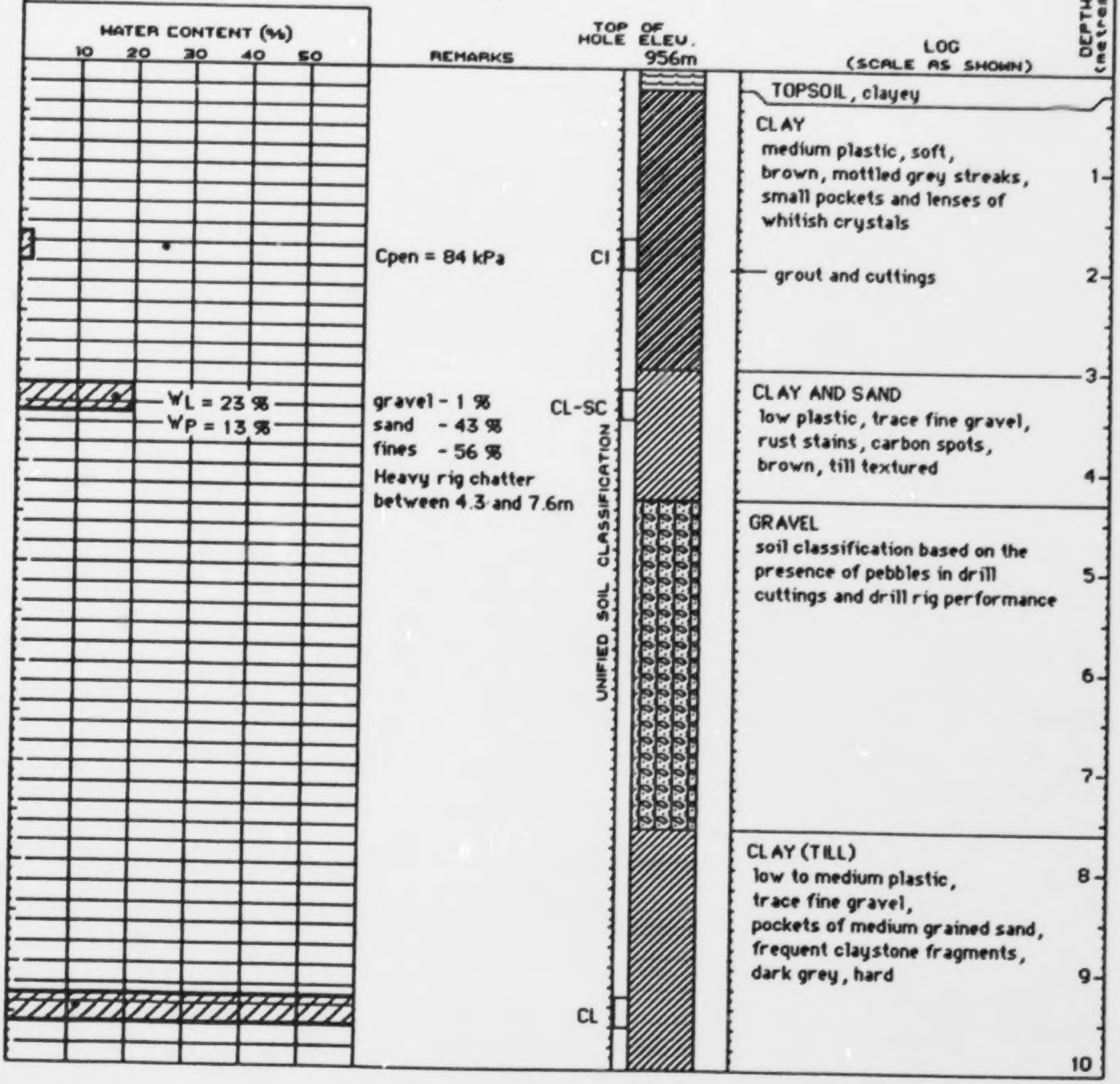
LOCATION . . See Drawing No. 2

CLIENT . . W-E-R Engineering Ltd.
PROJECT . . Little Bow River, Site 7A
DATE . . January 14, 1986
METHOD . . Mayhew 1000, wet rotary
DRILLING CO. . . SDS Drilling
INSPECTOR . . R. Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT ●
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P


WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV. 956m
LOG (SCALE AS SHOWN)
DEPTH (metres)
UNIFIED SOIL CLASSIFICATION
CI
CL-SC
CL
1
2
3
4
5
6
7
8
9
10

W_L = 23 %
W_P = 13 %

Cpen = 84 kPa

gravel - 1 %
sand - 43 %
fines - 56 %
Heavy rig chatter between 4.3 and 7.6m

TOPSOIL, clayey

CLAY
medium plastic, soft, brown, mottled grey streaks, small pockets and lenses of whitish crystals

grout and cuttings

CLAY AND SAND
low plastic, trace fine gravel, rust stains, carbon spots, brown, till textured

GRAVEL
soil classification based on the presence of pebbles in drill cuttings and drill rig performance

CLAY (TILL)
low to medium plastic, trace fine gravel, pockets of medium grained sand, frequent claystone fragments, dark grey, hard

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-3
Sheet 2 of 5

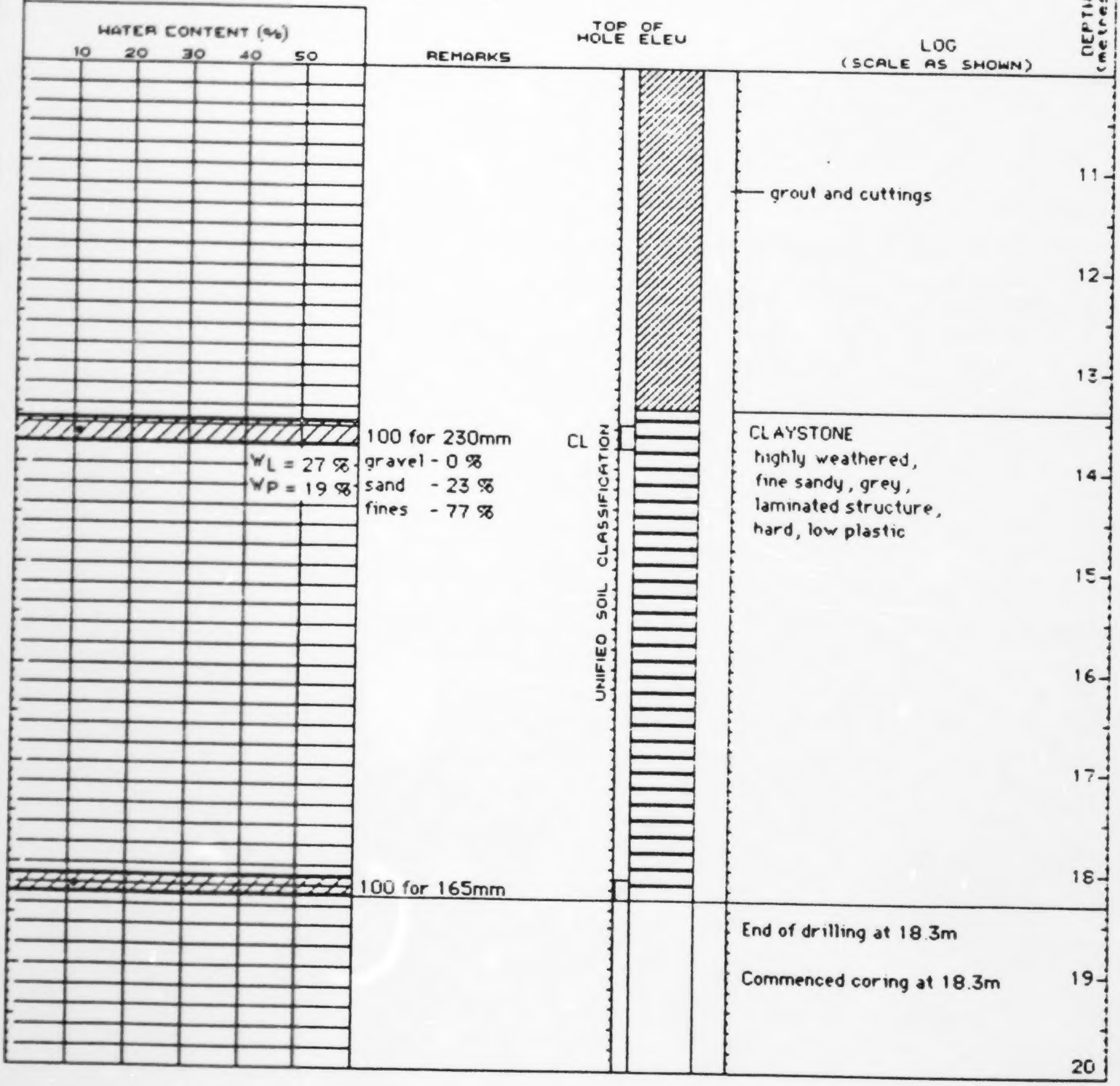
LOCATION See Drawing No 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 14, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P



WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV
LOG (SCALE AS SHOWN)
DEPTH (metres)
UNIFIED SOIL CLASSIFICATION
CL
11
12
13
14
15
16
17
18
19
20

grout and cuttings

100 for 230mm

W_L = 27 %
W_P = 19 %

gravel - 0 %
sand - 23 %
fines - 77 %

CLAYSTONE
highly weathered,
fine sandy, grey,
laminated structure,
hard, low plastic

100 for 165mm

End of drilling at 18.3m

Commenced coring at 18.3m

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO
86-3
Sheet 3 of 5

LOCATION See Drawing No. 2
RIG TYPE Mayhew 1000
BIT
GROUND ELEV. WATER LEVEL
CORE BARREL Christiansen
CASING DIA. CORE DIA. 73mm

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 14, 1986
METHOD Wet Rotary
DRILLING CO. SDS Drilling Ltd.
INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
						11
						12
						13
						14
						15
						16
				←	no instrumentation, grout and cuttings backfill	
						17
	18.3				Start of coring at 18.3m	18
W n=18% W L=40% W P=24% crse=15% silt=61% clay=24%	54 (0) 19.8	horizontally bedded, laminated to thickly bedded, fissured, frequent short randomly oriented slickensides, closly broken core	core loss		CLAYSTONE, very weak, silty, fine sand, completely weathered, blue-grey to black, occasional rust staining – highly weathered	19
						20

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO
86-3
Sheet 4 of 5

LOCATION: See Drawing No. 2
RIG TYPE: Mayhew 1000
BIT:
GROUND ELEV.: WATER LEVEL:
CORE BARREL: Christiansen
CASING DIA.: CORE DIA.: 73mm

CLIENT: W-E-R Engineering Ltd.
PROJECT: Little Bow River, Site 7A
DATE: January 14, 1986
METHOD: Wet Rotary
DRILLING CO.: SDS Drilling Ltd.
INSPECTOR: R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
γW = 2280 kg/m^3 γD = 1921 kg/m^3	91 (55) 21.6		▤		CLAYSTONE	21
	84 (68) 24.7	horizontally bedded, laminated to thickly bedded, fissured, occasional bedding joint	▨		SILTSTONE very weak, clayey, fine grained sand, highly weathered, dark grey, occasional red staining	22 23 24
	100 (92) 27.3	joint: 70° joint: 75° 3 joints: 40° joint: 25° joint: 60° joint: 80° 2 joints: 68°	▨	grout and cuttings backfill		25 26 27
W_n=19% W_L=53% W_P=28% sand=7% fines=93%	95 (85)	joint: 75° soft clay seam 150mm thick joint: 75° joint: 80° joint: 70° joint: 70°	▨		weak	28 29 30

FILE NO.
19-293-2

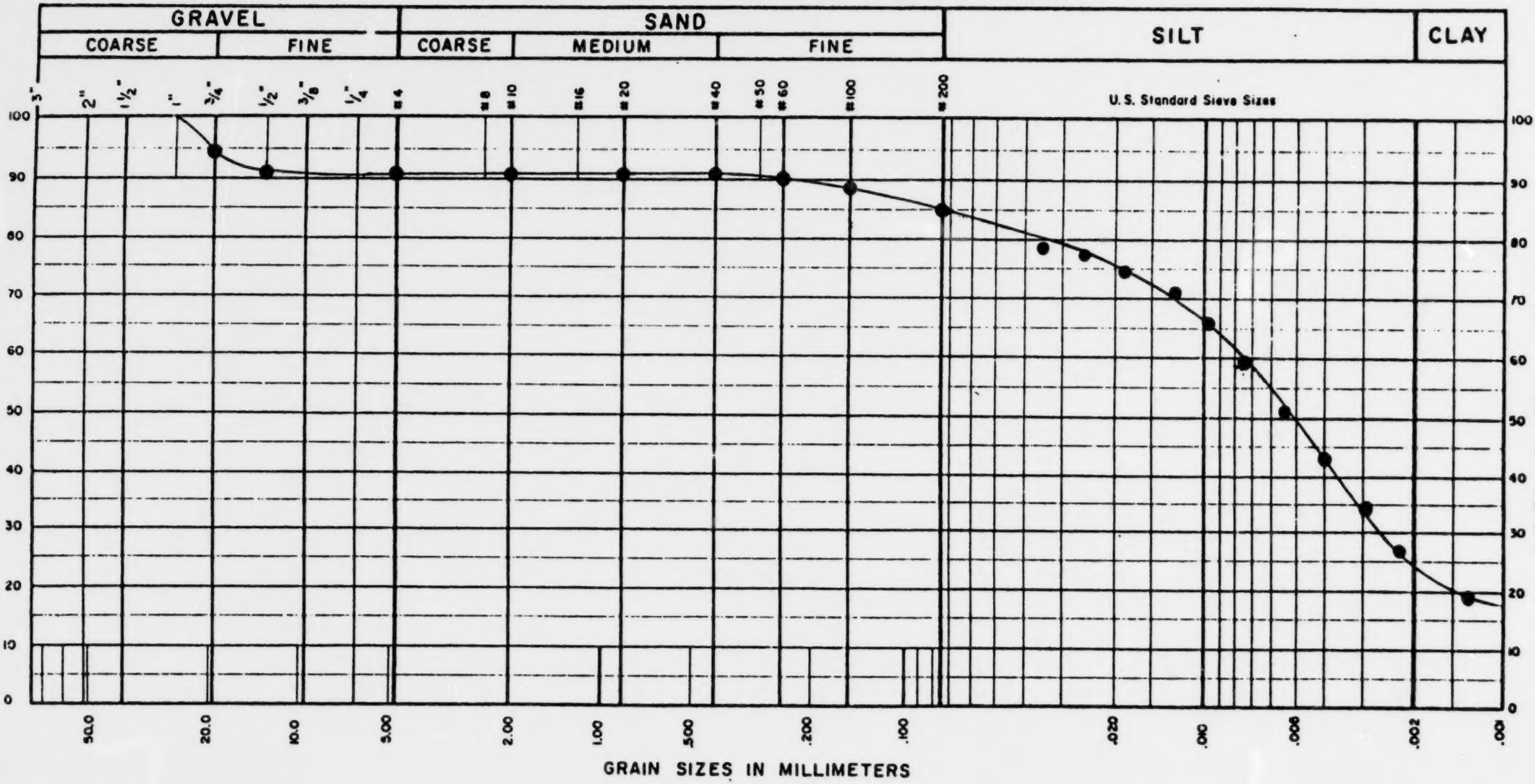
THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO.
86-3
Sheet 5 of 5

LOCATION See Drawing No. 2
CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
RIG TYPE Mayhew 1000
BIT
DATE January 14, 1986
GROUND ELEV. WATER LEVEL
METHOD Wet Rotary
CORE BARREL Christiansen
DRILLING CO. SDS Drilling Ltd.
CASING DIA. CORE DIA. 73mm
INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
	30.3 100 (82) 31.8	joint: 60° joint: 80°	▨		SILTSTONE ← grout and cuttings backfill	31
					Bottom of hole at target depth of 31.8m	32 33 34 35 36 37 38 39 40

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content	18 %	Clay	24 %
Liquid Limit	40	Silt	61
Plastic Limit	24	Sand	6
Plastic Index	16	Gravel	9

Classification CLAYSTONE, silty, trace fine sand, trace concretions, medium plasticity, Activity = 0.61, CI

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-3, 19.70 - 19.76 m
TEST DATE	FILE Nº [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO.
86-4
Sheet 1 of 4

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.

PROJECT Little Bow River, Site 7A

DATE January 9, 1986

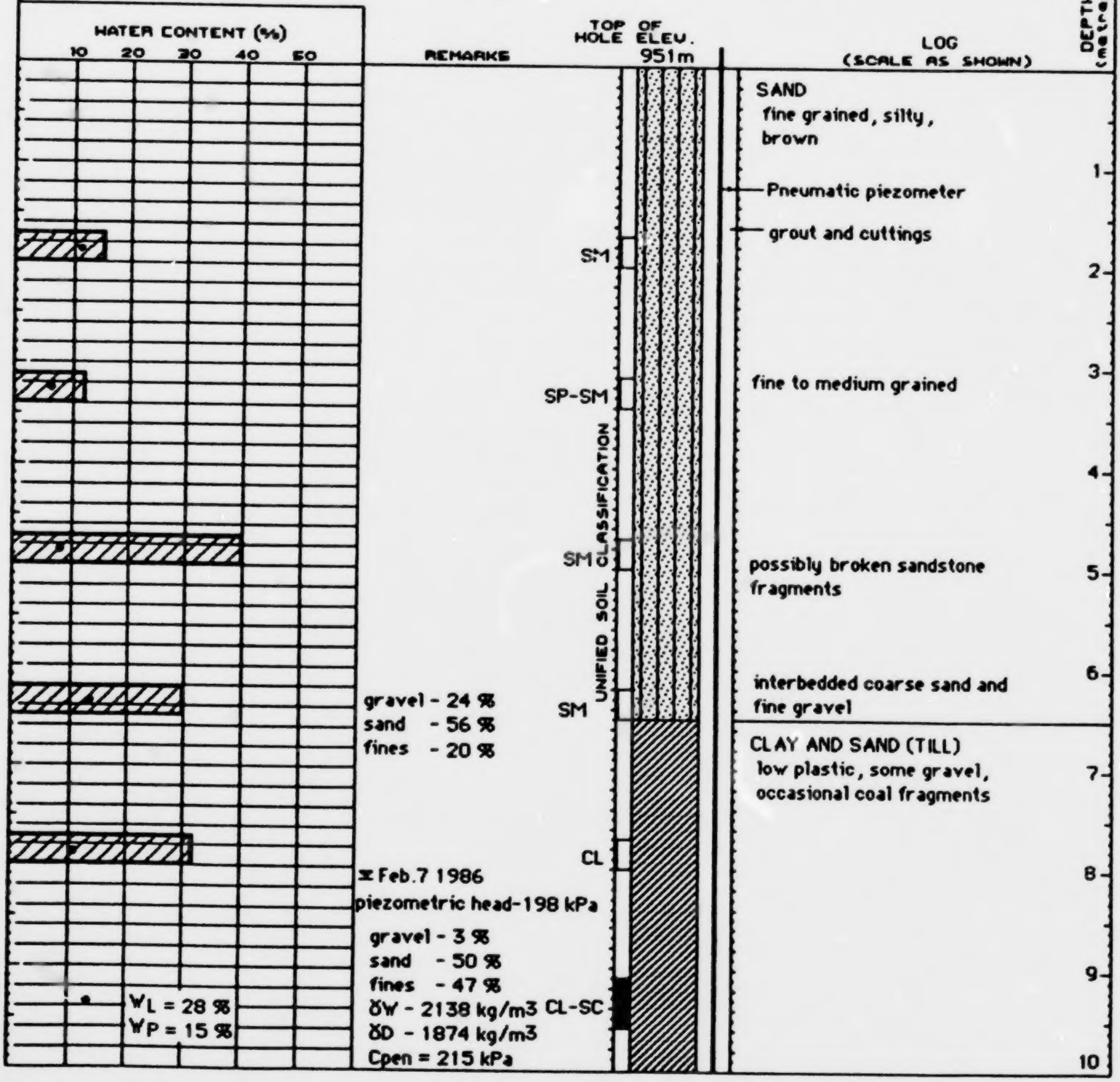
METHOD Mayhew 1000, wet rotary

DRILLING CO. SDS Drilling

INSPECTOR R. Hunt

LEGEND

SAMPLES			
DISTURBED	☐	WATER CONTENT	●
UNDISTURBED	■	WATER LEVEL	▽
NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P


WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV. 951m
LOG (SCALE AS SHOWN)
DEPTH (metres)
UNIFIED SOIL CLASSIFICATION
SM
SP-SM
SM
SM
CL
CL-SC
1
2
3
4
5
6
7
8
9
10

SAND
fine grained, silty, brown

Pneumatic piezometer

grout and cuttings

fine to medium grained

possibly broken sandstone fragments

interbedded coarse sand and fine gravel

gravel - 24 %
sand - 56 %
fines - 20 %

CLAY AND SAND (TILL)
low plastic, some gravel, occasional coal fragments

▽ Feb.7 1986
piezometric head-198 kPa

gravel - 3 %
sand - 50 %
fines - 47 %
γ_W - 2138 kg/m3
γ_D - 1874 kg/m3
Cpen = 215 kPa

W_L = 28 %
W_P = 15 %

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-4
Sheet 2 of 4

LOCATION See Drawing No 2

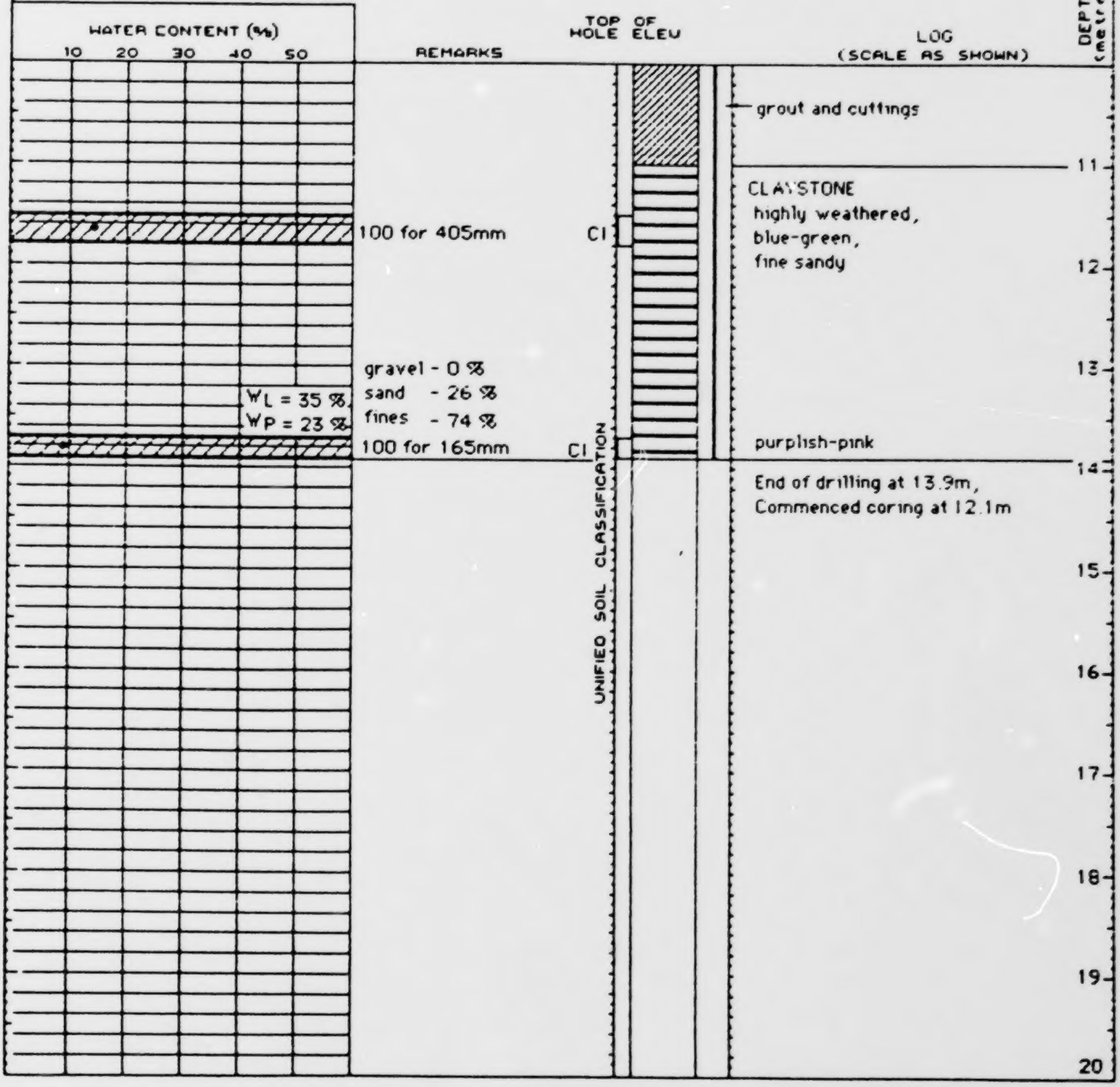
CLIENT W-E-R Engineering Ltd
PROJECT Little Bow River, Site 7A

DATE January 9, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P


WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
11
12
13
14
15
16
17
18
19
20

grout and cuttings

100 for 405mm — CI

CLAYSTONE
highly weathered,
blue-green,
fine sandy

W_L = 35 %
W_P = 23 %

gravel - 0 %
sand - 26 %
fines - 74 %

100 for 165mm — CI

purplish-pink

End of drilling at 13.9m,
Commenced coring at 12.1m

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO.
86-4
Sheet 3 of 4

LOCATION See Drawing No. 2
RIG TYPE Mayhew 1000
BIT
GROUND ELEV. WATER LEVEL
CORE BARREL Christiansen
CASING DIA. CORE DIA. 73mm

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 9, 1986
METHOD Wet Rotary
DRILLING CO. SDS Drilling Ltd.
INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
	12.1			pneumatic piezometer Petur P100 grout and cuttings backfill	Start of coring at 12.1m	11 12
SPT test to 13.9m	14 (0) 13.9	massive, friable, poor recovery to 13.9m due to SPT test	core loss		CLAYSTONE very weak, silty, highly weathered, dark grey, red staining	13
Wn=17% WL=33% WP=20% crse=11% silt=70% clay=19%	83 (33) 15.0	fissured, occasional short, randomly oriented slickensides broken core core loss joint: 70°			weak, fine grained sand, calcareous very weak, black	14
	100 (70)	soft clay seams, bentonitic, claystone fragments, 70 - 90mm thick				15
Wn=8% γW=2725 kg/m^3 γD=2534 kg/m^3		possible ice thrust fault			GRAVEL (TILL-LIKE) sandy, clayey, grey, crystalline pebbles, siltstone fragments	16
		thick, horizontal bedding joint: 86° joint: 70°			SILTSTONE weak, fine grained sand, moderately weathered, grey, calcareous	
		massive to thick, horizontal bedding, occasional bedding joint			SANDSTONE moderately weak, fine grained, silty, moderately weathered, grey, poorly indurated, calcareous	17
Wn=17% WL=53% WP=20% crse=30% silt=52% clay=18%	18.1	thick horizontal bedding, fissured, occasional short, randomly oriented slickensides			SILTSTONE weak, fine grained sand, highly weathered, dark grey to brown-grey, occasional red staining	18
Wn=30% WL=76% WP=37% sand=9% silt=58% clay=38%	89 (54)	laminated, friable joint: 70° soft clay seam, bentonitic, claystone fragments, concretions, 50mm thick soft clay seam as above, 100mm thick, occasional short, randomly oriented slickensides	core loss		clayey, very weak, dark grey, red stains, bentonitic layer of concretions sandy interbed, calcareous	19 20

FILE NO.		TEST HOLE NO.
19-293-2	**THURBER CONSULTANTS LTD.** **Geotechnical Engineers** **LOG OF TEST HOLE CORING**	86-4 Sheet 4 of 4

LOCATION See Drawing No. 2

RIG TYPE Mayhew 1000

BIT

GROUND ELEV. WATER LEVEL

CORE BARREL Christiansen

CASING DIA. CORE DIA. 73mm

CLIENT W-E-R Engineering Ltd.

PROJECT Little Bow River, Site 7A

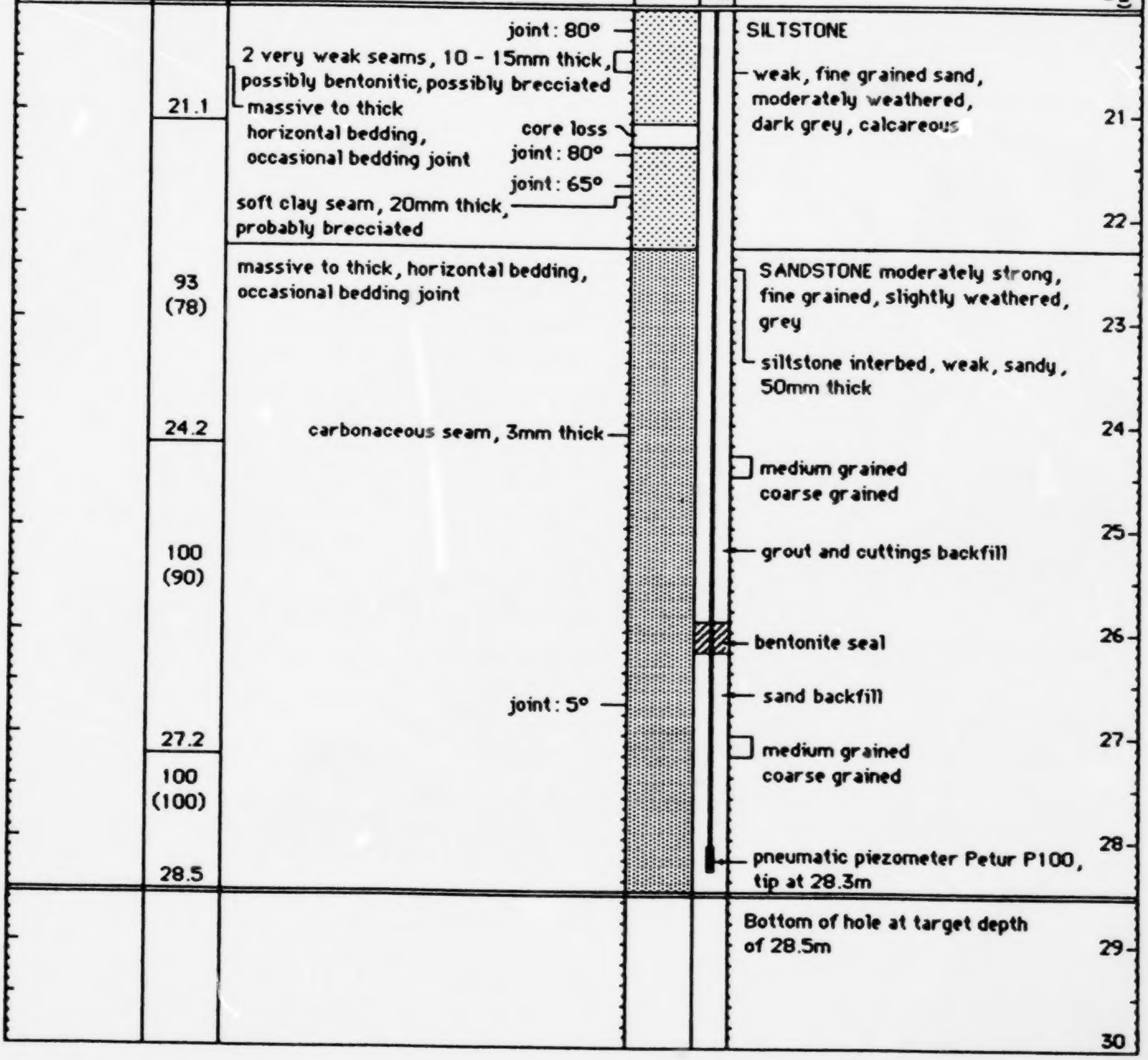
DATE January 9, 1986

METHOD Wet Rotary

DRILLING CO. SDS Drilling Ltd.

INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)



joint: 80°

2 very weak seams, 10 - 15mm thick, possibly bentonitic, possibly brecciated

massive to thick horizontal bedding, occasional bedding joint

core loss

joint: 80°

joint: 65°

soft clay seam, 20mm thick, probably brecciated

massive to thick, horizontal bedding, occasional bedding joint

carbonaceous seam, 3mm thick

joint: 5°

SILTSTONE

weak, fine grained sand, moderately weathered, dark grey, calcareous

SANDSTONE moderately strong, fine grained, slightly weathered, grey

siltstone interbed, weak, sandy, 50mm thick

medium grained
coarse grained

grout and cuttings backfill

bentonite seal

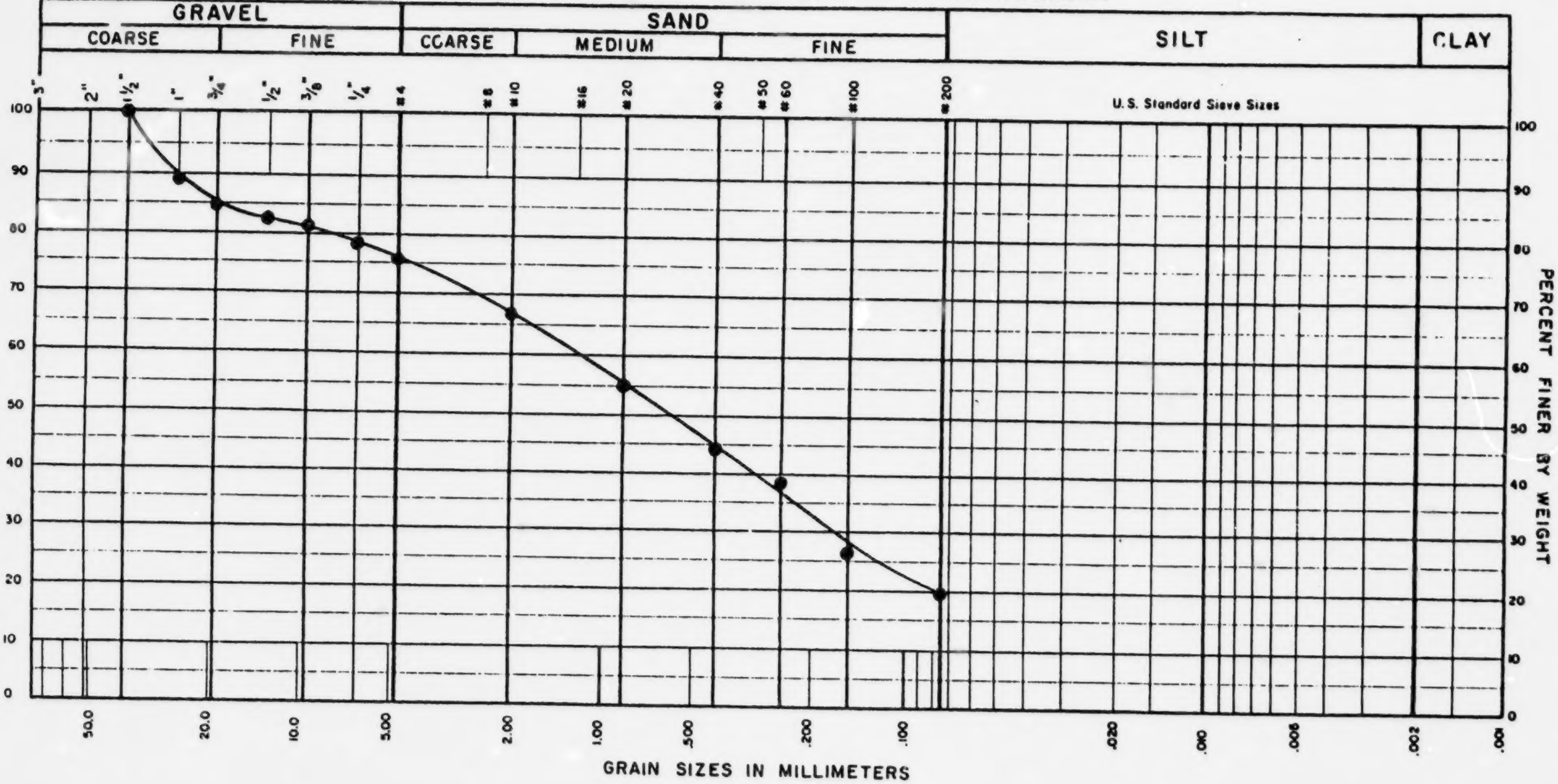
sand backfill

medium grained
coarse grained

pneumatic piezometer Petur P100, tip at 28.3m

Bottom of hole at target depth of 28.5m

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			12.6%
Liquid Limit			
Plastic Limit			
Plastic Index			

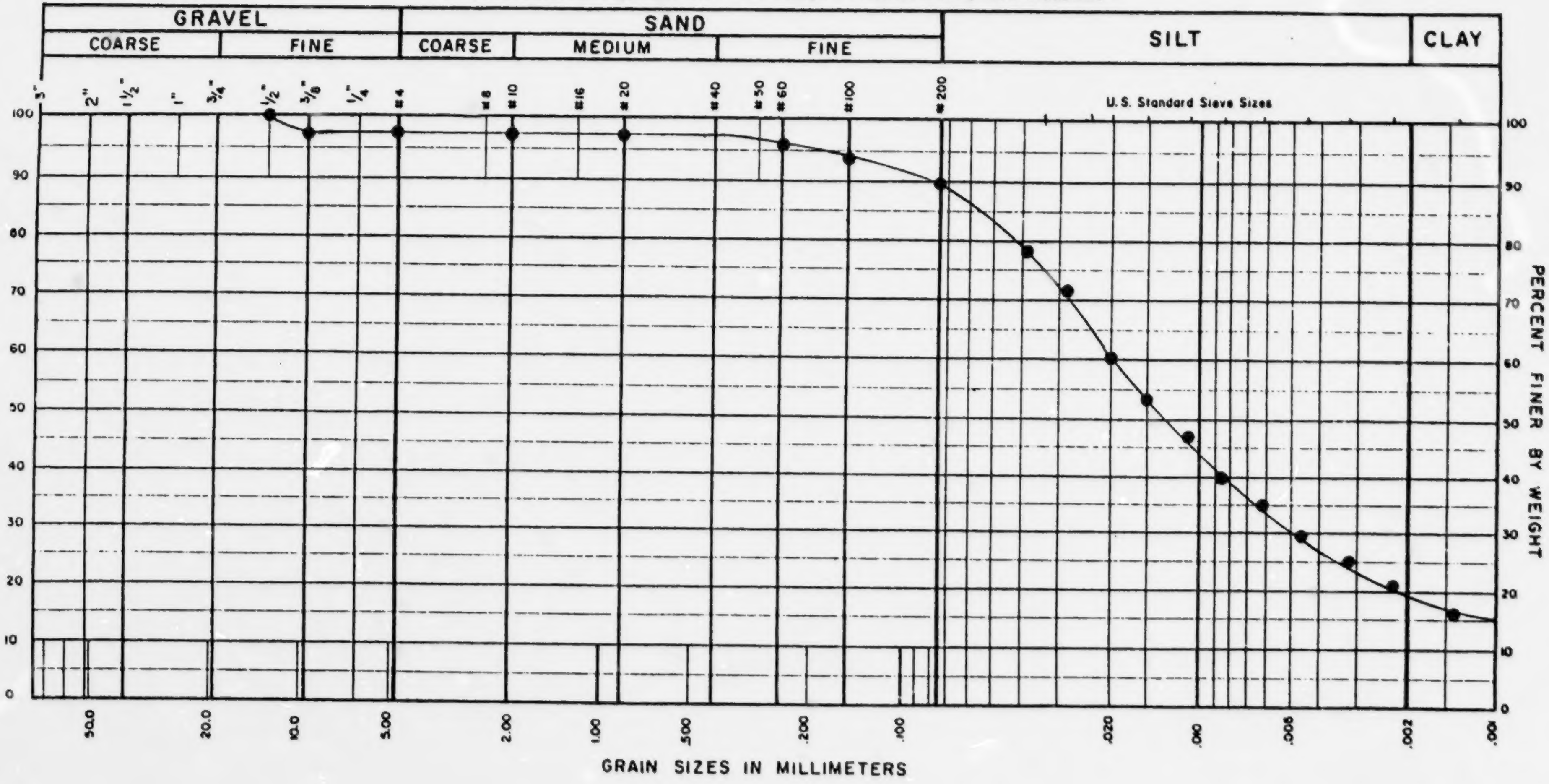
Clay			} %
Silt			}20
Sand			56
Gravel			24

Classification SAND, fine to medium, silty, occasional cemented clay lumps, SM

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-4, 6.4 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



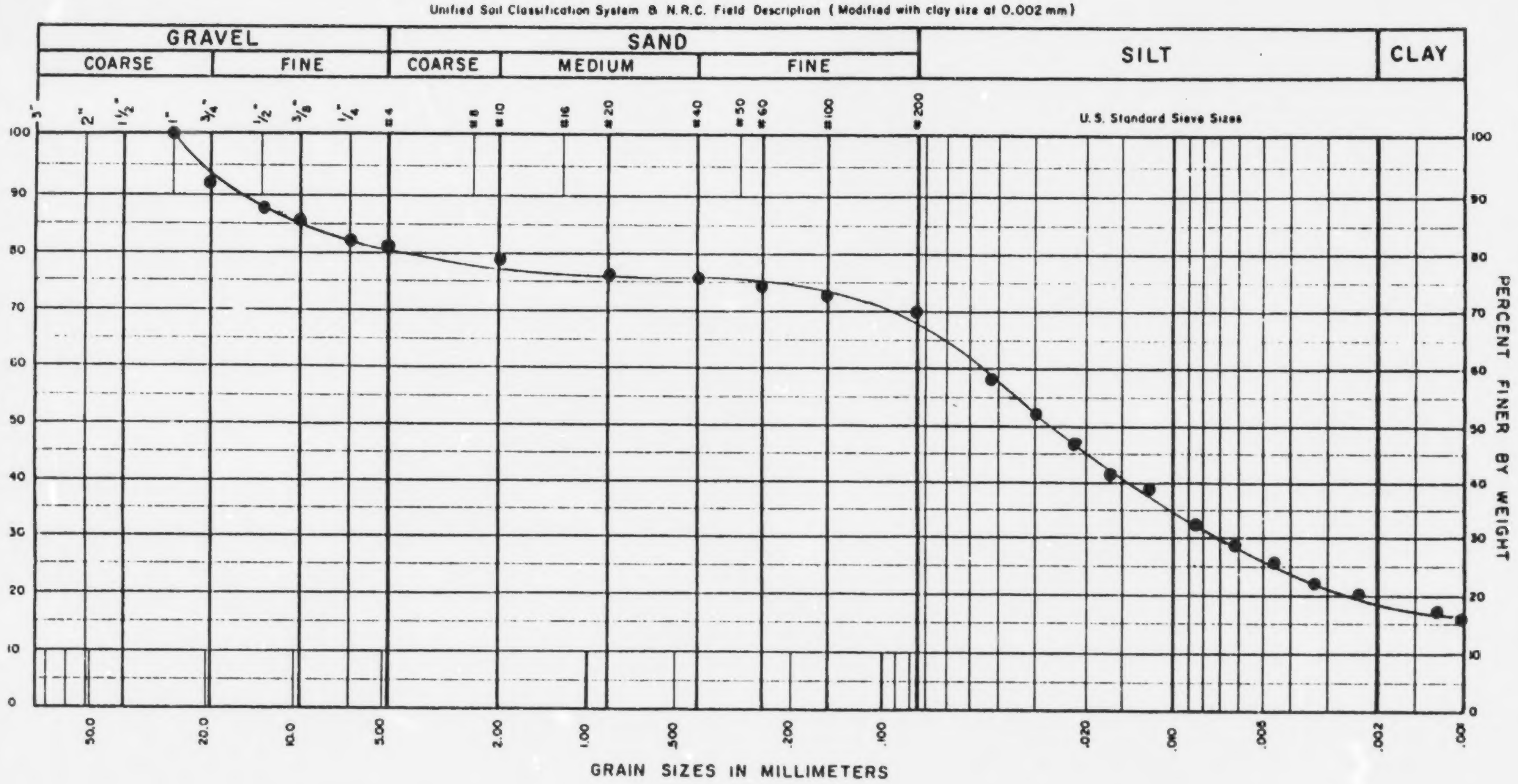
Nat. Water Content	17 %
Liquid Limit	33
Plastic Limit	20
Plastic Index	13

Clay	19 %
Silt	70
Sand	8
Gravel	3

Classification CLAYSTONE, silty, trace fine sand, trace concretions, medium plasticity, Activity = 0.67, CI

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-4, 14.69 - 14.76 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers



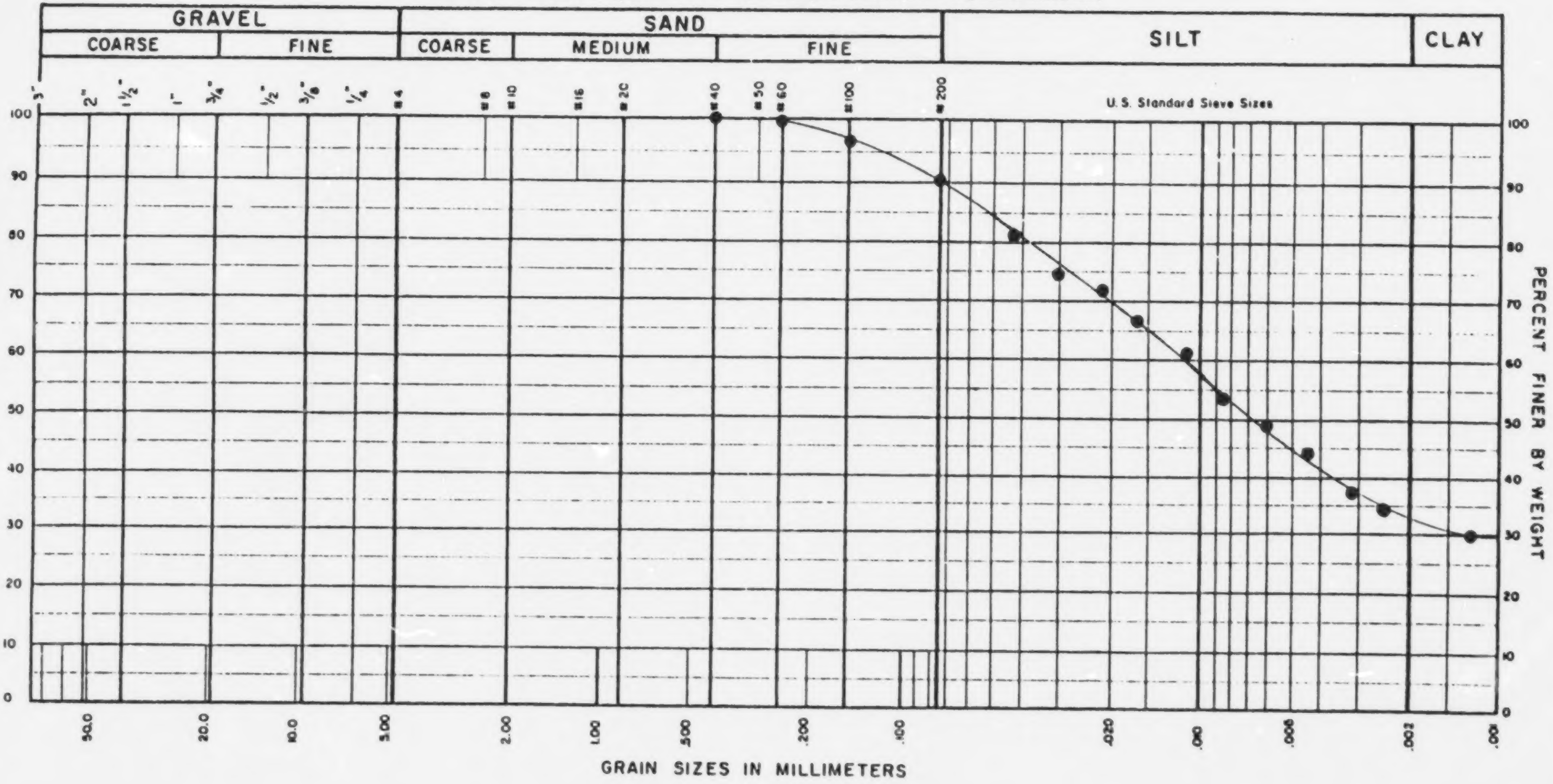
Nat. Water Content	17 %	Clay	18 %
Liquid Limit	53	Silt	52
Plastic Limit	20	Sand	11
Plastic Index	33	Gravel	19

Classification CLAYSTONE, silty, some sand, some gravel, high plasticity, bentonitic, Activity = 1.4, CH

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-4, 18.70 - 18.72 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content	30 %	Clay	33 %
Liquid Limit	76	Silt	58
Plastic Limit	37	Sand	9
Plastic Index	39	Gravel	-

Classification SILTSTONE, clayey, trace fine sand, high plasticity, bentonitic, Activity = 1.2, MH

THURBER CONSULTANTS LTD., Geotechnical Engineers

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-4, 19.05 - 19.15 m
TEST DATE	FILE Nº 19-293-2

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-5
sheet 1 of 3

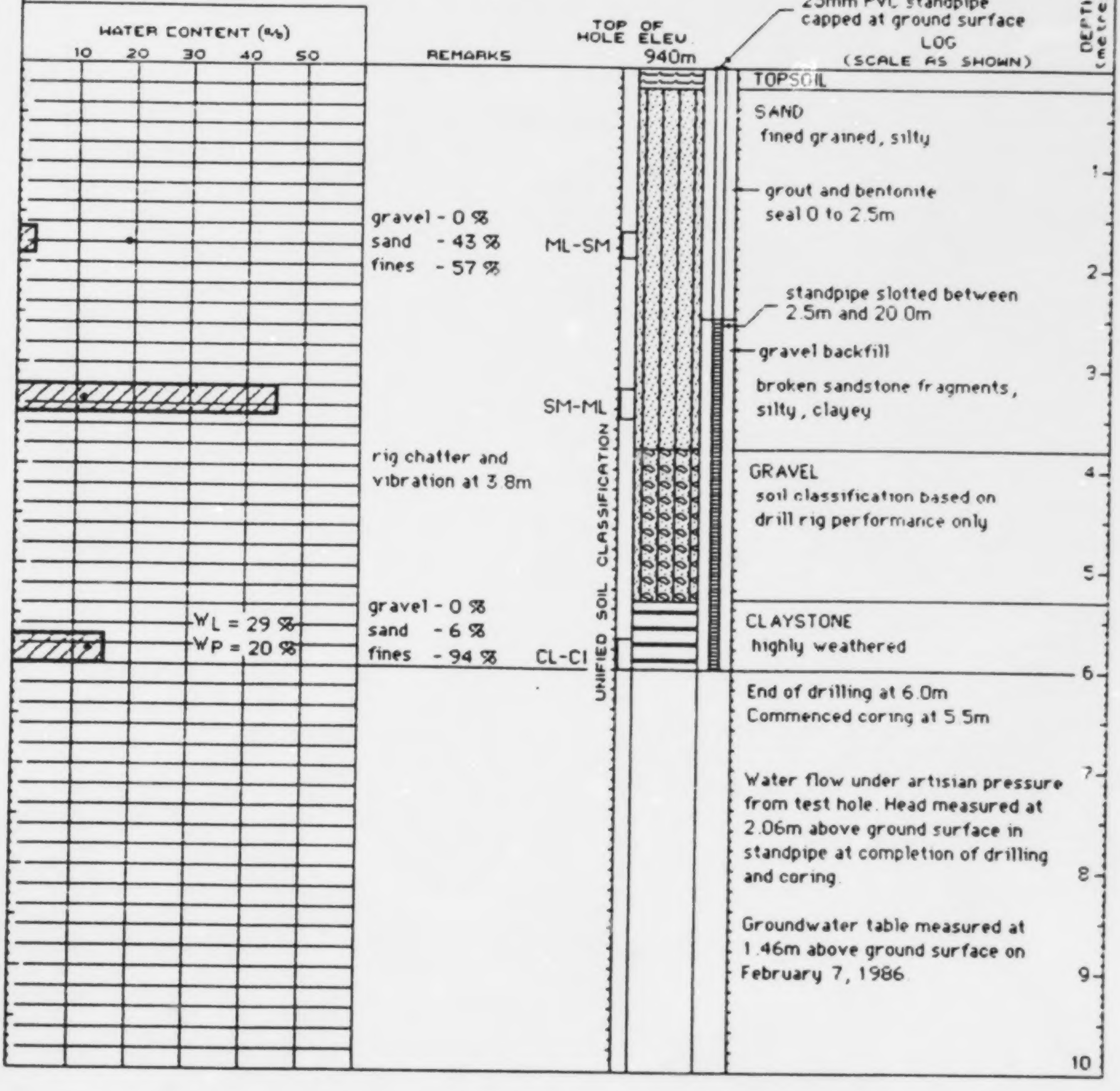
LOCATION See Drawing No 2

CLIENT W-E-R Engineering Ltd
PROJECT Little Bow River, Site 7A
DATE January 10, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P



WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV. 940m
LOG (SCALE AS SHOWN)
DEPTH (metres)
UNIFIED SOIL CLASSIFICATION
ML-SM
SM-ML
CL-CI
1
2
3
4
5
6
7
8
9
10

25mm PVC standpipe capped at ground surface

gravel - 0 %
sand - 43 %
fines - 57 %

rig chatter and vibration at 3.8m

gravel - 0 %
sand - 6 %
fines - 94 %

W_L = 29 %
W_P = 20 %

TOPSOIL

SAND
fined grained, silty

grout and bentonite seal 0 to 2.5m

standpipe slotted between 2.5m and 20.0m

gravel backfill

broken sandstone fragments, silty, clayey

GRAVEL
soil classification based on drill rig performance only

CLAYSTONE
highly weathered

End of drilling at 6.0m
Commenced coring at 5.5m

Water flow under artisian pressure from test hole. Head measured at 2.06m above ground surface in standpipe at completion of drilling and coring.

Groundwater table measured at 1.46m above ground surface on February 7, 1986

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO.
86-5
Sheet 2 of 3

LOCATION See Drawing No. 2
CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
RIG TYPE Mayhew 1000
BIT
DATE January 10, 1986
GROUND ELEV. WATER LEVEL
METHOD Wet Rotary
CORE BARREL Christiansen
DRILLING CO. SDS Drilling Ltd.
CASING DIA. CORE DIA. 73mm
INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
	5.5				25mm slotted PVC standpipe gravel backfill Start of coring at 5.5m	1 2 3 4 5
SPT test to 6.0m	4 (0) 6.8	fragmented core due to SPT test	core loss		CLAYSTONE very weak, silty, completely weathered, grey to brown-grey	6
	86 (86) 9.1	horizontal bedding, laminated, occasional bedding joint, friable			SILTSTONE very weak, fine grained sand, highly weathered, dark grey	7 8
		possible ice thrust fault fragmented zone 140mm thick	core loss		gravel (till like), sandy, clayey, crystalline pebbles SANDSTONE	9 10

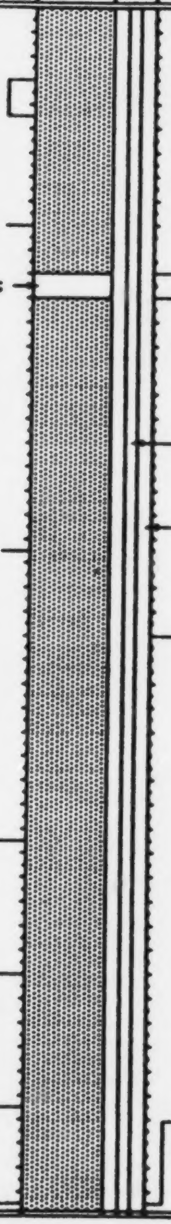
FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

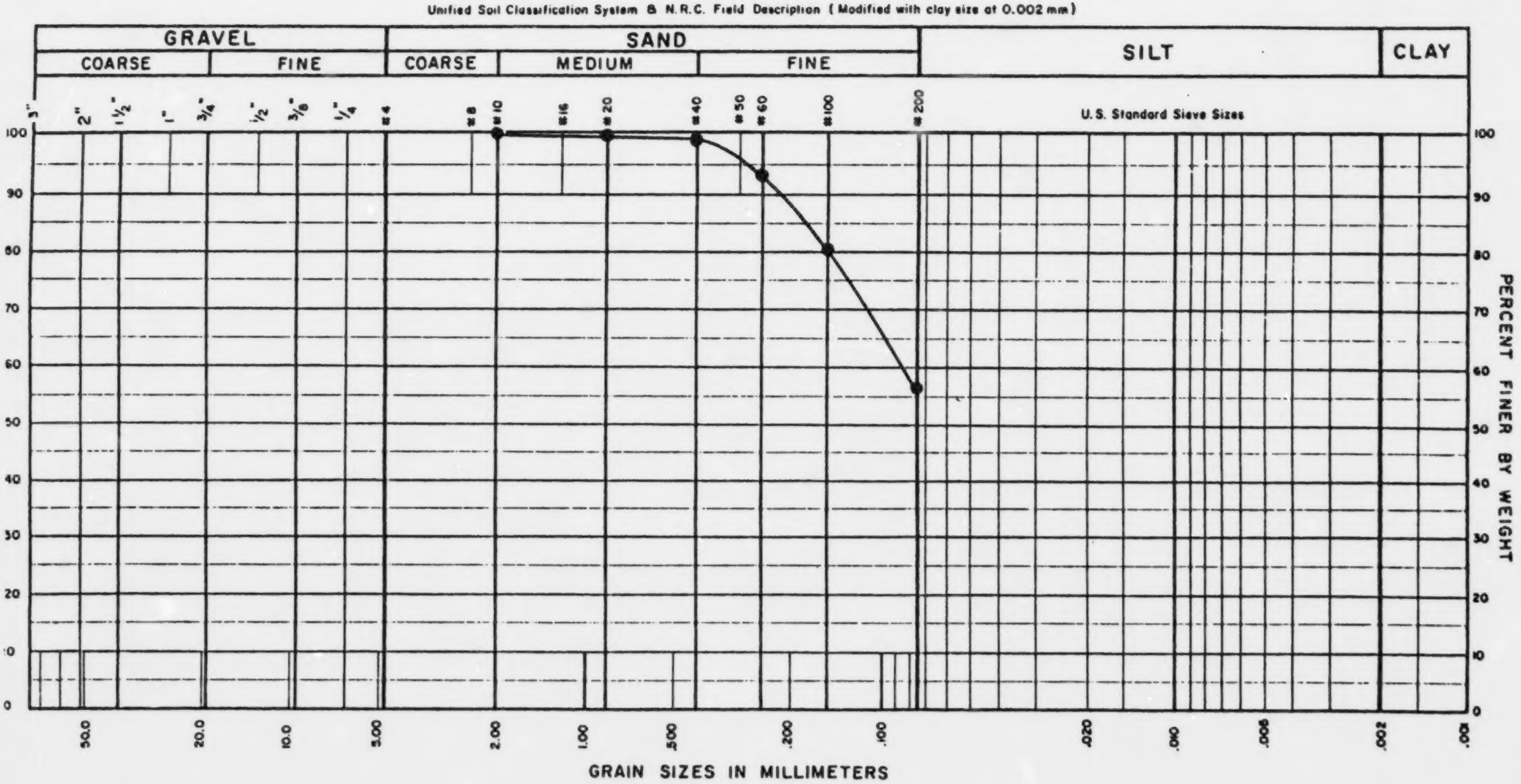
TEST HOLE NO.
86-5
Sheet 3 of 3

LOCATION: See Drawing No. 2
RIG TYPE: Mayhew 1000
BIT:
GROUND ELEV.: WATER LEVEL:
CORE BARREL: Christiansen
CASING DIA.: CORE DIA.: 73mm

CLIENT: W-E-R Engineering Ltd.
PROJECT: Little Bow River, Site 7A
DATE: January 10, 1986
METHOD: Wet Rotary
DRILLING CO.: SDS Drilling Ltd.
INSPECTOR: R. Hunt / L. E. Nesset



TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUTIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
	91 (75)	massive to thickly bedded, occasional bedding joint			SANDSTONE strong to very strong, fine to medium grained, moderately weathered, grey, occasional carbonaceous lamina, occasional siltstone interbed	
		bedding: 80 - 90°				11
		joint: 45°				
	12.2					12
		core loss			probable very weak siltstone bed	
					medium to coarse grained sandstone, slightly weathered	13
	93 (85)				25mm slotted PVC standpipe	
					gravel backfill	14
		joint: 60°				
	15.2				very strong	15
	100 (96)					16
		joint: 40°				17
	17.4					
	100 (92)	joint: 80°				18
		2 joints: 55°			carbonaceous seam 100mm thick	19
	20.0	fragmented zone 130mm thick			Bottom of test hole at target depth of 20.0m	20



Nat. Water Content	19.5%
Liquid Limit	
Plastic Limit	
Plastic Index	

Clay	} %
Silt	} 57
Sand	43
Gravel	0

Classification SILT and SAND, fine grained, ML-SM

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-5, 1.8 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-6
Sheet 1 of 3

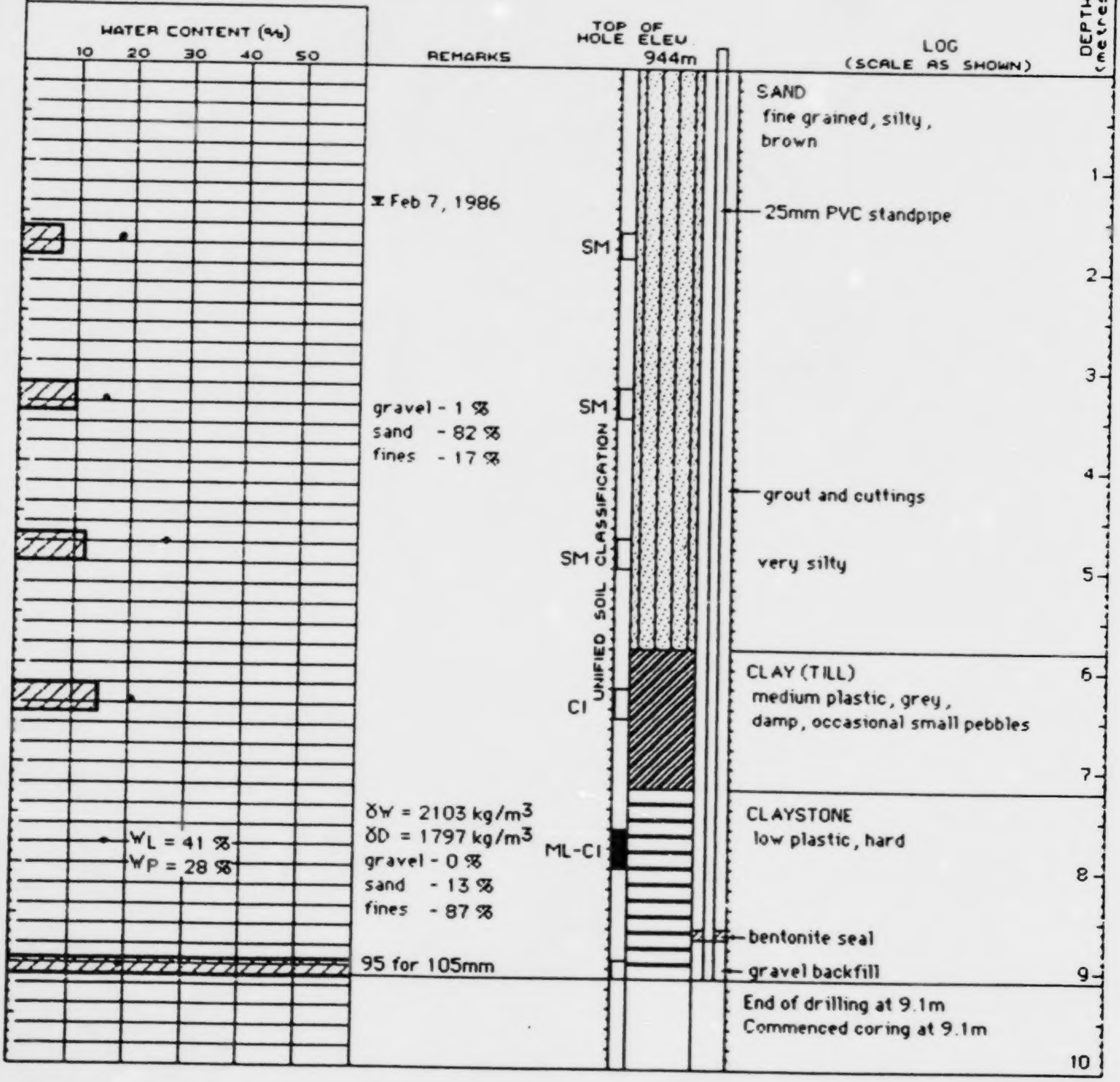
LOCATION See Drawing No 2

CLIENT W-E-R Engineering Ltd
PROJECT Little Bow River, Site 7A

DATE January 11, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES: DISTURBED	☐	WATER CONTENT	●
SAMPLES: UNDISTURBED	■	WATER LEVEL	▼
SAMPLES: NO RECOVERY	☒	LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P


WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV 944m
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
1
2
3
4
5
6
7
8
9
10
SM
SM
SM
CI
ML-CI
25mm PVC standpipe
grout and cuttings
bentonite seal
gravel backfill

▼ Feb 7, 1986

gravel - 1 %
sand - 82 %
fines - 17 %

W_L = 41 %
W_P = 28 %

γW = 2103 kg/m^3
γD = 1797 kg/m^3
gravel - 0 %
sand - 13 %
fines - 87 %

95 for 105mm

SAND
fine grained, silty, brown

very silty

CLAY (TILL)
medium plastic, grey, damp, occasional small pebbles

CLAYSTONE
low plastic, hard

End of drilling at 9.1m
Commenced coring at 9.1m

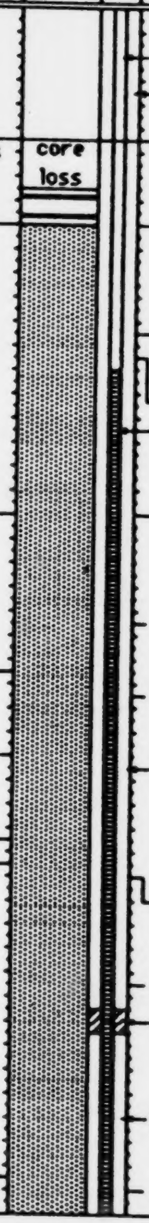
FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO.
86-6
Sheet 2 of 3

LOCATION See Drawing No. 2
RIG TYPE Mayhew 1000
BIT
GROUND ELEV. WATER LEVEL
CORE BARREL Christiansen
CASING DIA. CORE DIA. 73mm

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 11, 1986
METHOD Wet Rotary
DRILLING CO. SDS Drilling Ltd.
INSPECTOR R. Hunt / L. E. Nesset



TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
					25mm PVC standpipe gravel backfill	
	9.1				Start of coring at 9.1m	9
		horizontal bedding, laminated, numerous bedding joints: 85 - 90°, gradational contact	core loss		CLAYSTONE weak, silty, fine grained sand, moderately weathered, dark grey	
	86 (59)	horizontal bedding, occasional cross-bedding, occasional bedding joint: 85 - 90°			SANDSTONE moderately weak, fine grained, silty, moderately weathered, grey, occasional carbonaceous lamina	10
					siltstone bed 230mm thick strong, slightly weathered standpipe slotted below 11.0m	11
	12.2	joint: 75°			siltstone interbed 3mm thick	12
	100 (93)				very strong	13
		joint: 75°			medium grained	
		joint: 3°			gravel backfill	14
	15.1	joint: 58° breccia interbed 10mm thick				15
					coarse grained	
	100 (82)				alternating fine and medium grained beds	16
					bentonite seal	
					gravel backfill	17
	17.8	joint: 22°			very strong	18

FILE NO
19-293-2

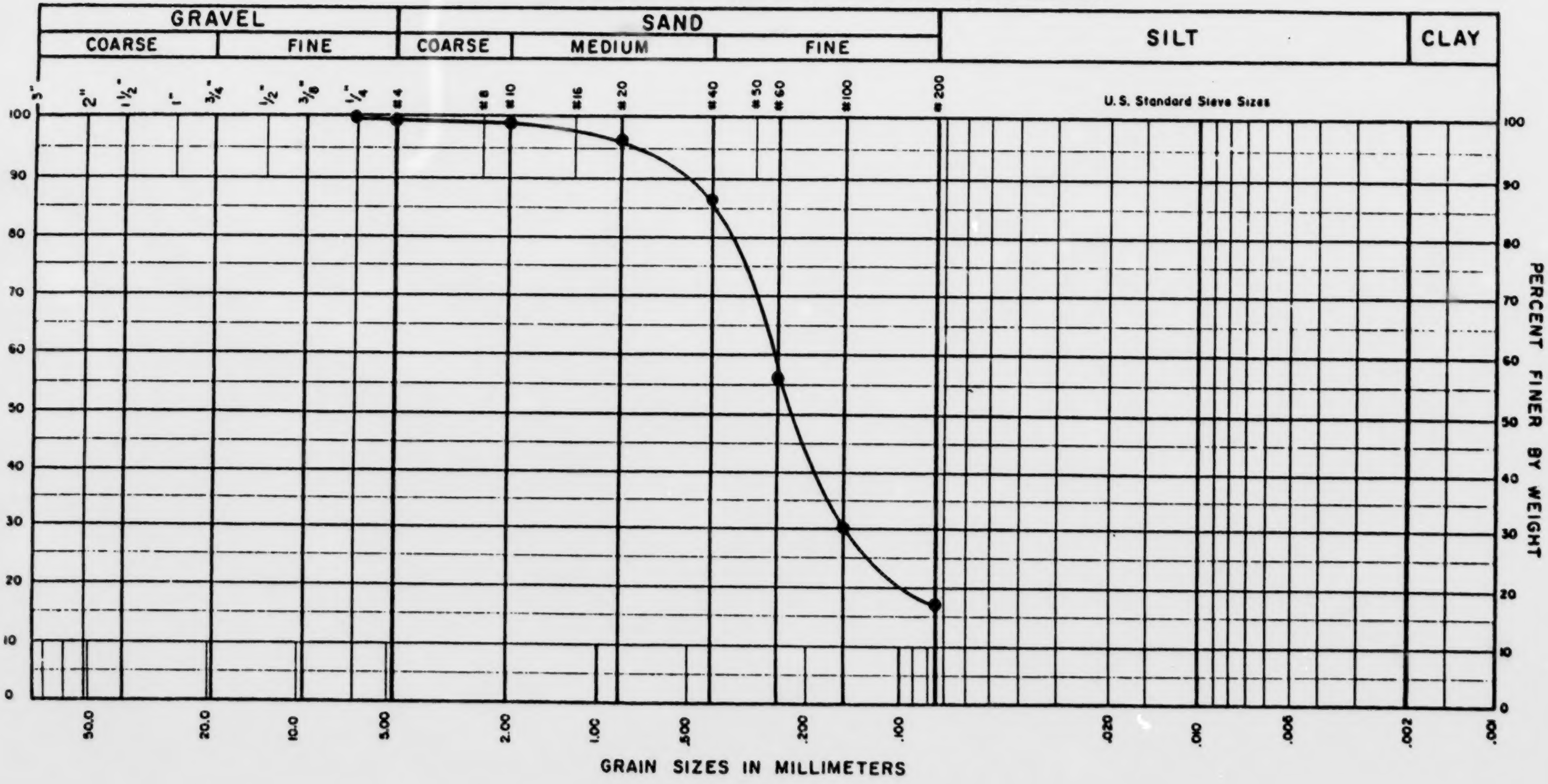
THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO
86-6
Sheet 3 of 3

LOCATION See Drawing No 2
CLIENT W-E-R Engineering Ltd
PROJECT Little Bow River, Site 7A
RIG TYPE Mayhew 1000
BIT
DATE January 11, 1986
GROUND ELEV WATER LEVEL
METHOD Wet Rotary
CORE BARREL Christiansen
DRILLING CO SDS Drilling Ltd
CASING DIA. CORE DIA. 73mm
INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
	100 (85)	joint: 15°			SANDSTONE 25mm slotted PVC standpipe gravel backfill	19
Wn = 15% WL=45% WP=27%	20.8				coarse grained	20
sand=7% silt=76% clay=17%	100 (40) 21.6	horizontal bedding, broken core			SILTSTONE, weak, clayey, moderately weathered, dark grey moderately strong, fine grained sand slightly bentonitic	21
					Bottom of test hole at target depth of 21.6m	22
						23
						24
						25
						26
						27
						28

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



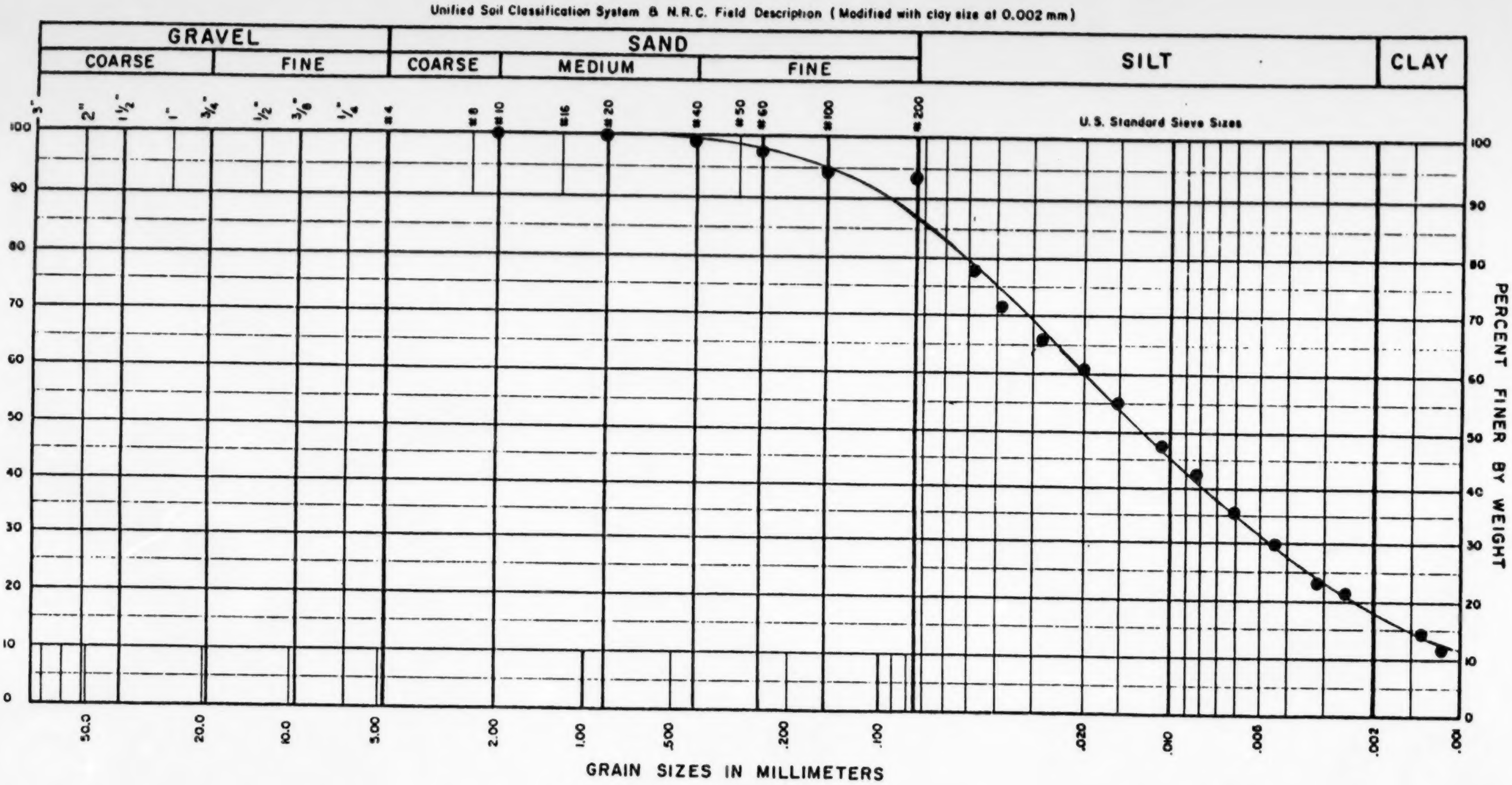
Nat. Water Content			15.2%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay			} %
Silt			} 17
Sand			82
Gravel			1

Classification SAND, fine grained, silty, SM

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-6, 3.3 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			- %
Liquid Limit			45
Plastic Limit			27
Plastic Index			18

Clay			17 %
Silt			76
Sand			7
Gravel			-

Classification SILTSTONE, some clay, trace fine sand, low plasticity, slightly bentonitic, Activity = 1.1, ML

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-6, 20.68 - 20.80 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

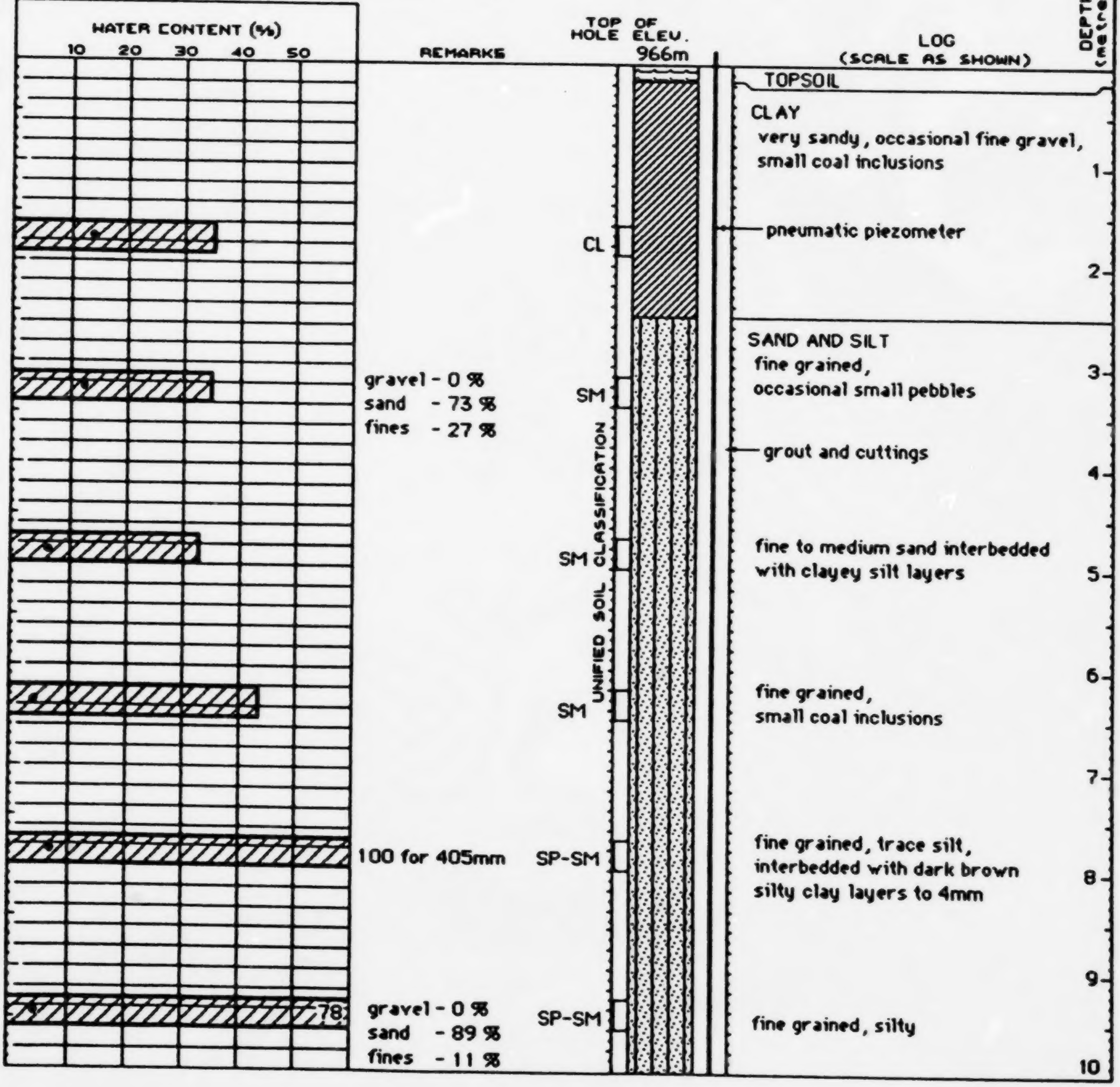
TEST HOLE NO.
86-7
Sheet 1 of 6

LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 12, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES				
DISTURBED	☐		WATER CONTENT	•
UNDISTURBED	■		WATER LEVEL	▼
NO RECOVERY	☒		LIQUID LIMIT	W_L
			PLASTIC LIMIT	W_P


WATER CONTENT (%)
10
20
30
40
50
78
TOP OF HOLE ELEV. 966m
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
1
2
3
4
5
6
7
8
9
10

REMARKS	UNIFIED SOIL CLASSIFICATION	LOG
		TOPSOIL
	CL	CLAY very sandy, occasional fine gravel, small coal inclusions pneumatic piezometer
gravel - 0 % sand - 73 % fines - 27 %	SM	SAND AND SILT fine grained, occasional small pebbles grout and cuttings
	SM	fine to medium sand interbedded with clayey silt layers
	SM	fine grained, small coal inclusions
100 for 405mm	SP-SM	fine grained, trace silt, interbedded with dark brown silty clay layers to 4mm
gravel - 0 % sand - 89 % fines - 11 %	SP-SM	fine grained, silty

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO.
86-7
Sheet 2 of 6

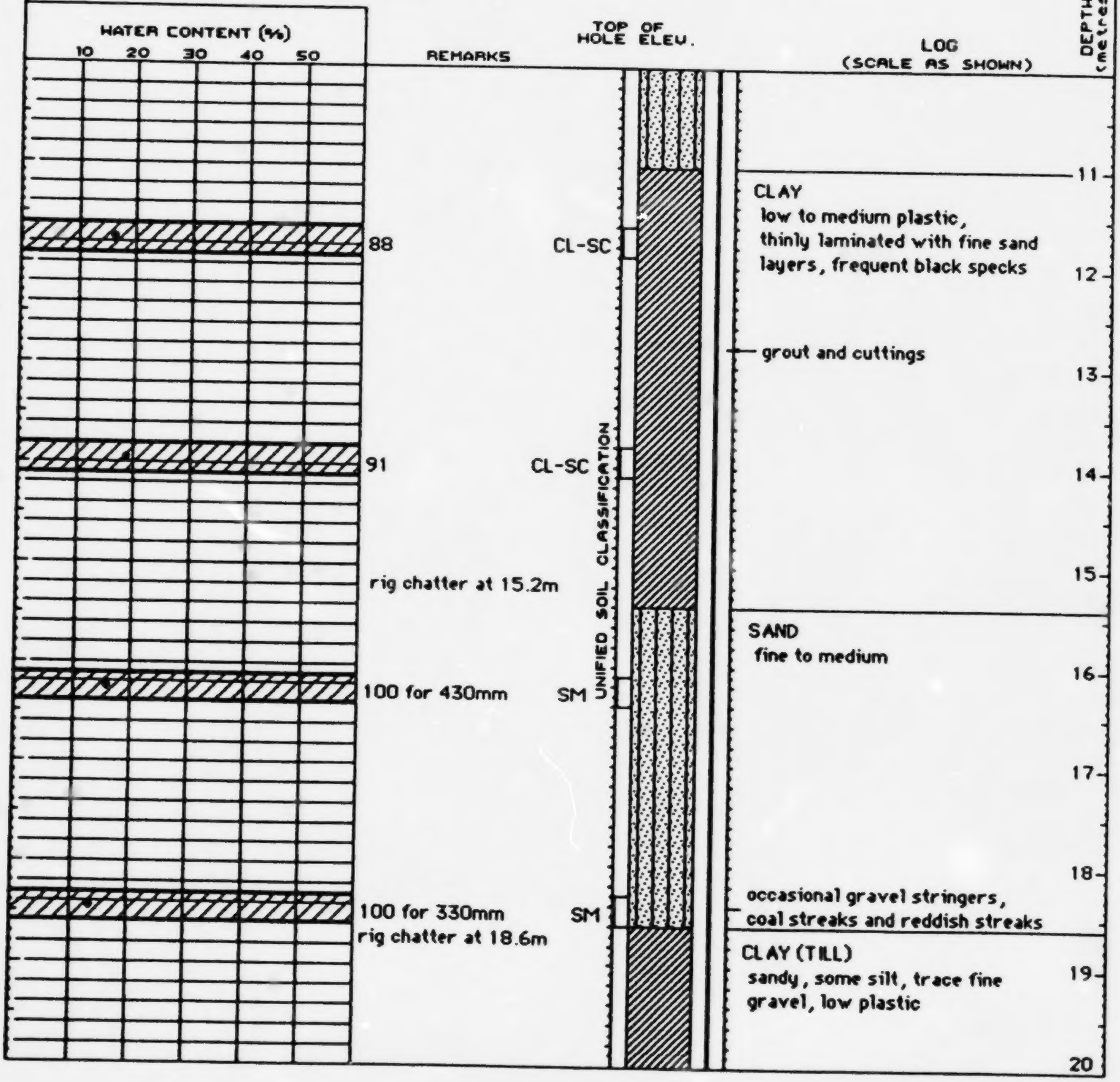
LOCATION See Drawing No. 2

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 12, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R. Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P



WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV.
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
11
12
13
14
15
16
17
18
19
20

REMARKS	UNIFIED SOIL CLASSIFICATION
88	CL-SC
91	CL-SC
rig chatter at 15.2m	
100 for 430mm	SM
100 for 330mm rig chatter at 18.6m	SM

CLAY
low to medium plastic, thinly laminated with fine sand layers, frequent black specks

grout and cuttings

SAND
fine to medium

occasional gravel stringers, coal streaks and reddish streaks

CLAY (TILL)
sandy, some silt, trace fine gravel, low plastic

FILE NO
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

TEST HOLE NO
86-7
Sheet 3 of 6

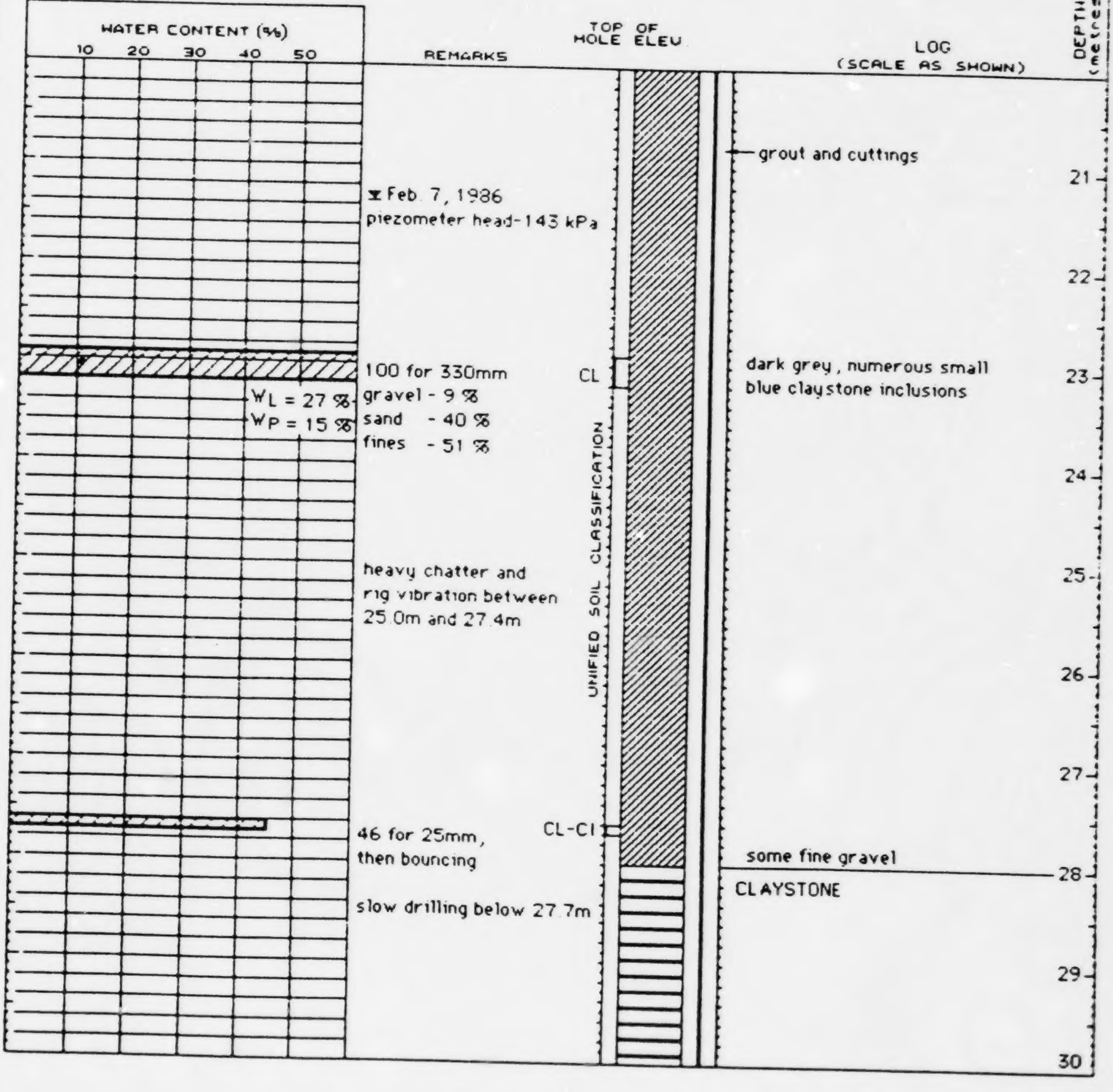
LOCATION See Drawing No 2

CLIENT W-E-R Engineering Ltd
PROJECT Little Bow River, Site 7A
DATE January 12, 1986
METHOD Mayhew 1000, wet rotary
DRILLING CO. SDS Drilling
INSPECTOR R Hunt

LEGEND

SAMPLES
- DISTURBED ☐
- UNDISTURBED ■
- NO RECOVERY ☒

WATER CONTENT •
WATER LEVEL ▼
LIQUID LIMIT W_L
PLASTIC LIMIT W_P



WATER CONTENT (%)
10
20
30
40
50
REMARKS
TOP OF HOLE ELEV
UNIFIED SOIL CLASSIFICATION
LOG (SCALE AS SHOWN)
DEPTH (metres)
21
22
23
24
25
26
27
28
29
30
CL
CL-CI

$W_L = 27\%$
$W_P = 15\%$

▼ Feb. 7, 1986
piezometer head - 143 kPa

100 for 330mm
gravel - 9 %
sand - 40 %
fines - 51 %

heavy chatter and rig vibration between 25.0m and 27.4m

46 for 25mm, then bouncing

slow drilling below 27.7m

grout and cuttings

dark grey, numerous small blue claystone inclusions

some fine gravel

CLAYSTONE

FILE NO		TEST HOLE NO
19-293-2		86-7 Sheet 4 of 6

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE

LOCATION	See Drawing No 2	CLIENT	W-E-R Engineering Ltd
		PROJECT	Little Bow River, Site 7A
		DATE	January 12, 1986
		METHOD	Mayhew 1000, wet rotary
		DRILLING CO	SDS Drilling
		INSPECTOR	R. Hunt

LEGEND

SAMPLES			
DISTURBED ☐		WATER CONTENT	•
UNDISTURBED ■		WATER LEVEL	▼
NO RECOVERY ☒		LIQUID LIMIT	W_L
		PLASTIC LIMIT	W_P

WATER CONTENT (%) 10 20 30 40 50	REMARKS	UNIFIED SOIL CLASSIFICATION	TOP OF HOLE ELEV	LOG (SCALE AS SHOWN)	DEPTH (metres)
				End of drilling at 30.5m Commenced coring at 30.5m	
					31
					32
					33
					34
					35
					36
					37
					38
					39
					40

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO.
86-7
Sheet 5 of 6

LOCATION See Drawing No. 2
RIG TYPE Mayhew 1000
BIT
GROUND ELEV. WATER LEVEL
CORE BARREL Christiansen
CASING DIA. CORE DIA. 73mm

CLIENT W-E-R Engineering Ltd.
PROJECT Little Bow River, Site 7A
DATE January 13, 1986
METHOD Wet Rotary
DRILLING CO. SDS Drilling Ltd.
INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
					grout and cuttings backfill Start of coring at 30.5m	
	73 (24)	horizontally bedded, laminated, occasional bedding joint, broken core	core loss		CLAYSTONE, very weak, silty, fine grained sand, highly weathered, black-brown	31
		possible ice thrust fault			GRAVEL (TILL-LIKE) fine to coarse, subangular to round, sandy, clayey, grey, crystalline pebbles	32
	33.2	massive, horizontal bedding and cross bedding at 70 - 80°, occasional bedding joint, rare gypsum coating on joints			SANDSTONE very strong, fine to coarse grained, (fining upwards), slightly weathered, grey, occasional carbonaceous lamina	33
	100 (42)	joint: 35° joint: 60°			bentonite seal	34
	34.4				medium grained	
	100 (95)				sand backfill	35
					pneumatic piezometer, Petur P100, tip at 36.0m	36
	36.3	joint: 68°			fine to medium grained	
	100 (96)				sand backfill	37
		joint: 72° joint: 22°				
						38
	38.8	joint: 75°				
	100 (78)	2 joints: 50°				39
		joint: 10°			coal seam 4mm thick	
	39.8	joint: 40°			interbedded weak siltstone and fine grained silty sandstone	40

FILE NO.
19-293-2

THURBER CONSULTANTS LTD.
Geotechnical Engineers
LOG OF TEST HOLE CORING

TEST HOLE NO.
86-7
Sheet 6 of 6

LOCATION See Drawing No. 2

RIG TYPE Mayhew 1000

BIT

GROUND ELEV. WATER LEVEL

CORE BARREL Christiansen

CASING DIA. CORE DIA. 73mm

CLIENT W-E-R Engineering Ltd.

PROJECT Little Bow River, Site 7A

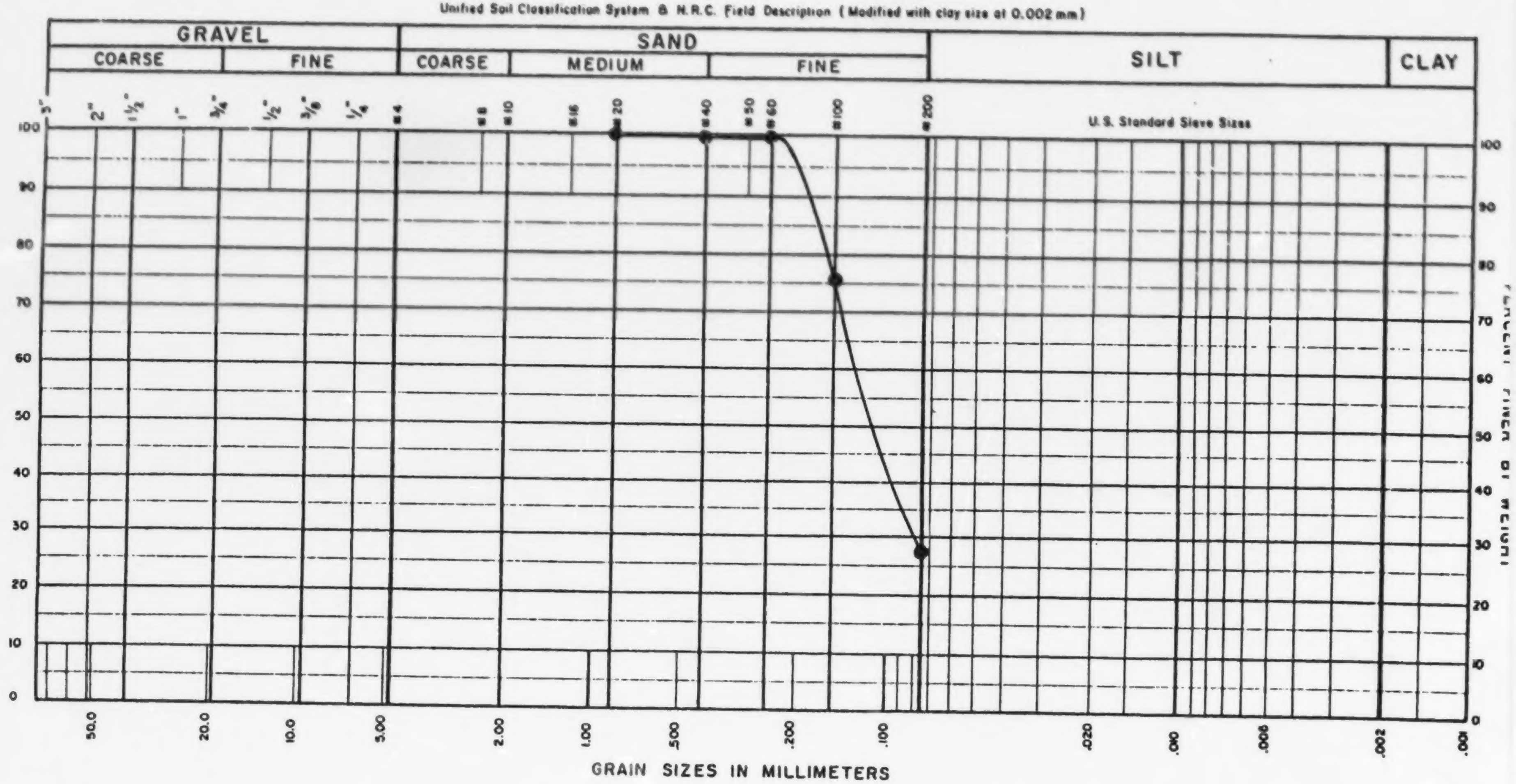
DATE January 13, 1986

METHOD Wet Rotary

DRILLING CO. SDS Drilling Ltd.

INSPECTOR R. Hunt / L. E. Nesset

TEST RESULTS	REC'Y (RQD) (%)	DISCONTINUITIES DESCRIPTION	ROCK TYPE	INSTR. DETAILS	ROCK DESCRIPTION	DEPTH (METRES)
	83 (47)		▨		SANDSTONE interbedded siltstone and sandstone	
WL=30% WP=20% sand=16% fines=84%	41.8	horizontally bedded, laminated, fissured, occasional short randomly oriented slickensides	☰		CLAYSTONE very weak to moderately weak, silty, highly weathered, brown-grey, grey and black beds	41
					Bottom of test hole at target depth of 41.8m	42
						43
						44
						45
						46
						47
						48
						49
						50



Nat. Water Content			11.7%
Liquid Limit			
Plastic Limit			
Plastic Index			

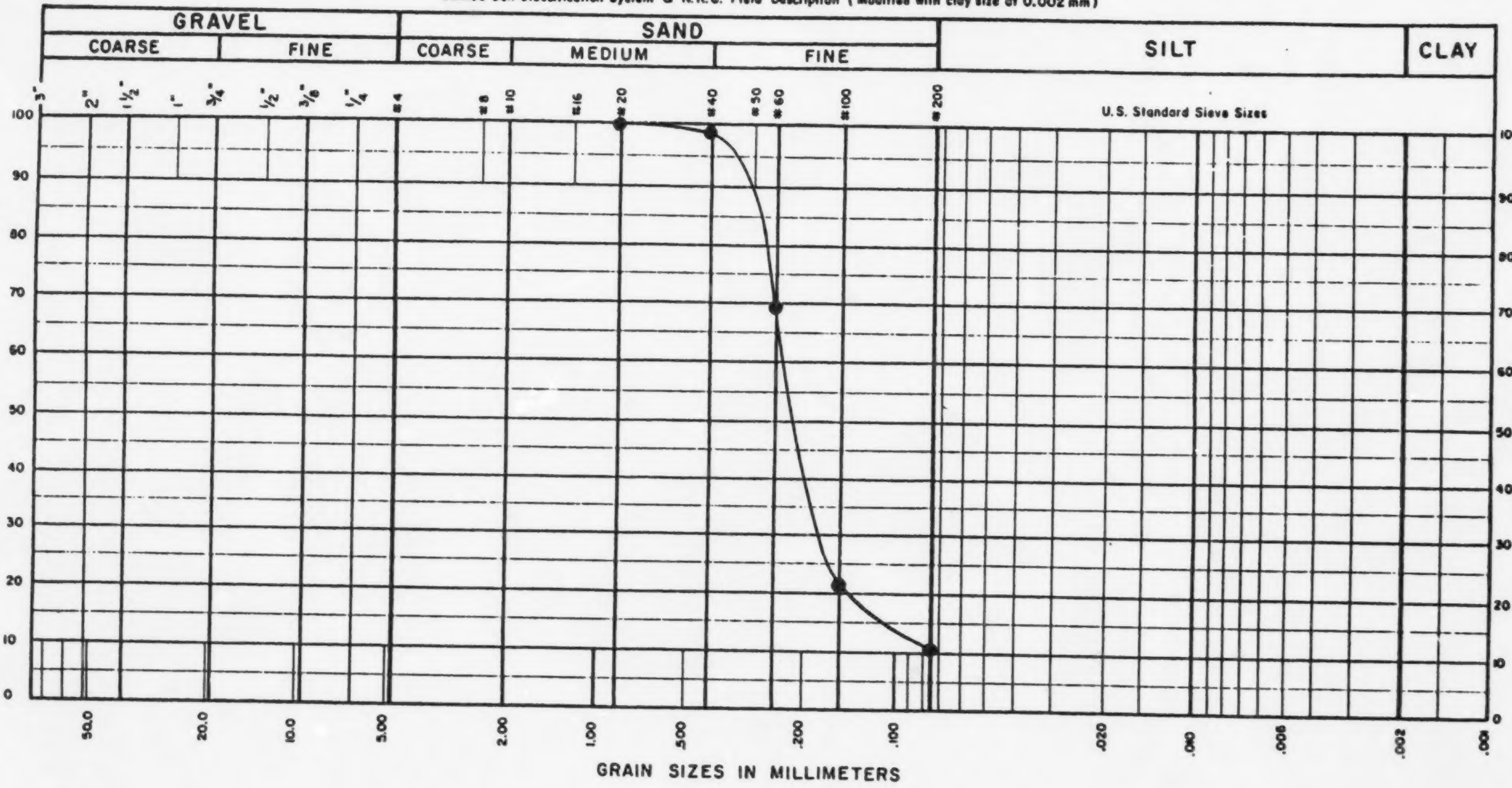
Clay		}	%
Silt		}	27
Sand			73
Gravel			0

Classification SAND and SILT, fine grained, SM

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-7, 3.3 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			4.9 %
Liquid Limit			
Plastic Limit			
Plastic Index			

		%
Clay		
Silt		11
Sand		89
Gravel		0

Classification SAND, fine grained, silty SP-SM

CLIENT	W-E-R Engineering Ltd.
PROJECT	Little Bow River, Site 7A
LOCATION	
SAMPLE	TH 86-7, 9.5 m
TEST DATE	FILE Nº 19-293-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
SITE 7A
FEASIBILITY DESIGN REPORT
March, 1986

APPENDIX C

DETAILED SUMMARY OF DESIGN STUDIES AND COST ESTIMATES

TABLE OF CONTENTS

		Page No.
1.0	GENERAL	C-1
2.0	BASE DATA	C-1
3.0	BASIC PROJECT REQUIREMENTS	C-1
	3.1 Reservoir Sizing	C-1
	3.2 Freeboard	C-2
	3.3 Design Floods	C-2
	3.4 Low Level Irrigation Requirements/ Storage Utilization	C-3
4.0	GENERAL LAYOUT AND SELECTION OF ELEMENTS	C-3
	4.1 General	C-3
	4.2 Spillways	C-4
	4.3 Low Level Irrigation Conduits	C-7
5.0	BASIS OF COSTING	C-8

LIST OF TABLES

Title	Table No.
Detailed Cost Estimate - Little Bow Site 7A 61 700 dam^3 (50,000 ac.ft.)	C1
Pertinent Data - Little Bow Site 7A 61 700 dam^3 (50,000 ac.ft.)	C2
Detailed Cost Estimate - Little Bow Site 7A 86 300 dam^3 (70,000 ac.ft.)	C3
Pertinent Data - Little Bow Site 7A 86 300 dam^3 (70,000 ac.ft.)	C4

LIST OF DRAWINGS

Title	Drawing No.
Little Bow Site 7A - 61 700 dam^3 (50,000 ac.ft.)	C1
Little Bow Site 7A - 86 300 dam^3 (70,000 ac.ft.)	C2

1.0 General

This section covers the site layouts, hydraulic and structural design, and costing aspects of the main dam and appurtenant works for the two reservoir storage alternatives under consideration for Little Bow Site 7A. General layouts are shown in Drawings C1 and C2. Pertinent data and costs are shown in tables C1 through C4.

2.0 Base Data

These feasibility studies have utilized the hydrologic and storage data as provided in Appendix A, and the geotechnical assessment as outlined in Appendix B, in support of designs for the dams and structures.

Photogrammetric mapping for Site 7A produced for the previous conceptual and feasibility studies (References 1 and 2) was also used in this study. This mapping was prepared at a scale of 1:10,000 with two-metre contour intervals.

3.0 Basic Project Requirements

The following subsections outline the project requirements established as a basis for preparing the feasibility designs and cost estimates for the two alternatives.

3.1 Reservoir Sizing

In accordance with the terms of this study, the reservoir alternatives were sized at 61 700 and 86 300 dam^3 (50,000 and 70,000 ac.ft.).

Based on topography and reservoir damage aspects it has been established that the physical maximum reservoir size at Site 7A would be about 86 300 dam^3 (70,000 ac.ft.). The area-capacity curve used to establish FSL's for the two reservoir alternatives incorporates topography generated for the 7B-1 feasibility study (Reference 2).

The relationship between available water supply and reservoir size is presented in the yield-storage curves provided in Appendix A.

3.2 Freeboard

Freeboard above the full supply level (FSL) for each dam alternative (3-3.1 m) was calculated to include an allowance for wind setup and wave runup as well as appropriate allowances for gate operational failure and frost action.

3.3 Design Floods

Guidelines as established by the Dam Safety Branch of Alberta Environment were adhered to in setting the design criteria outlined below:

- spillways were sized to efficiently handle the 1:100 - 147.3 m^3/s (structure design) flood with a minimum of wave height freeboard on the dam.

- spillways are also capable of passing the 0.5 PMF - 322.8 m^3/s (project) flood with a minimum of 0.3 m of freeboard remaining on the dam. Hydrographs for the 1:100 and 0.5 PMF flood inflows are provided in Appendix A.

3.4 Low Level Irrigation Requirements/Storage Utilization

Requirements for the project dictate that the low level conduit be capable of releasing a flow of 8.5 m^3/s (300 cfs) at minimum reservoir levels, for irrigation purposes. The sill level of the conduit intake structure was set slightly below the floodplain, for each alternative, in order to fully utilize the reservoir's storage capability without encroaching on the live storage.

4.0 General Layout and Selection of Elements

4.1 General

The Site 7A dam centreline location used for the conceptual design study (Reference 1) was essentially retained for the current feasibility investigation.

The general layouts as shown in Drawings C1 and C2 represent the feasibility level structural investigations as carried out for this study. The layouts were determined on the basis of topographic suitability. Locations for the spillway and conduit as shown for the conceptual design were essentially retained for this study.

Embankment designs used in this investigation are outlined in Appendix B. The cost estimates presented herein reflect the nature of the material excavated and the quantities of borrow required. Included in the cost estimate is a provision for overhaul of impervious borrow material to reflect the possibility that good borrow sources may be located 2 to

3 km from the damsite as discussed in Appendix B. Consideration was given to an alternate embankment design requiring less impervious and more random fill. However, a preliminary cost analyses indicated that the cost saving for this alternate design would be minimal.

The proposed embankment sections are zone-type earthfills with 4:1 upstream and 3:1 downstream slopes and a 6 m crest width. Seepage under the dam would be controlled by an upstream impervious blanket, cutoff trench, relief wells and downstream reverse filter blanket. A granular filter in conjunction with a toe drain will also be required to control seepage through the embankment. Slope protection will consist of rock riprap placed on a gravel bed. Removal of soft foundation soils is also proposed for site preparation purposes.

The predicted embankment settlement at the damsite for each alternative requires that crests be cambered to ensure maintenance of the required freeboard should such movements occur. However, dam crest elevations shown in the structure layouts only reflect the levels required to accommodate the selected reservoir sizes. Precise elevations along the crest (including camber) would be determined during final design. None-the-less, embankment quantities calculated for costing purposes include an allowance for this configuration.

4.2 Spillways

a) Hydraulic Design

The spillways proposed for each alternative are gated chute type structures with hydraulic jump stilling basins. Spillways equipped with radial gates were selected as being the most cost effective. It has been assumed that gate operators will be available for the project, however, normal gate operation will be automated.

Spillway dimensions are based on optimization studies to determine the most economical combination of crest length and gate height to pass the required flood flows. Chutes are flared into the stilling basin to ensure that flow energy is adequately dissipated.

The spillways are designed to efficiently pass the 1:100 year flood (structure design flood). The structures are also sized to handle floods up to one-half the probable maximum flood (0.5 PMF) with the possibility of limited damage being sustained in the lower structural components of the spillway during the passage of such floods.

The sizing of the radial gates and determination of the corresponding routed outflows is dependent on assumptions regarding the operation of the gates during flood events. For the purposes of this report it was assumed that during flood events the gates would be operated automatically to maintain the reservoir level at FSL as long as possible and then to completely open when the reservoir level rises above FSL. The rating curves provided are based on an average weir coefficient of 2.10 (metric) with the gates fully opened during passage of floods.

Entrance lengths for the crest section have been increased beyond hydraulic requirements to allow for piers, radial gates, hoists and a service bridge deck.

Basic spillway dimensions for the two alternatives may be found in Drawings C1 and C2 and Tables C2 and C4.

b) Location

Spillway structures have been essentially located to take advantage of topographic and foundation conditions. Spillway profiles are configured to minimize excavation depths. Approach channels are clay lined to minimize seepage problems and have been aligned to ensure that high velocities do not endanger the upstream abutment of the dam. Avoidance of downstream erosion near the toe of the dam was the main objective in determining the exit channel alignment. Materials excavated from the spillways can be utilized in the main dam embankments.

c) Structural Design

The spillway structures are of conventional reinforced concrete design, with structural components sized approximately by comparison with similar existing works. The required space and supports for the radial gates, hoisting systems and upstream bulkheads are provided by adequately sized piers and abutments. Gate hoists, controls and additional equipment would be located on a hoisting deck spanning between the piers. The deck would also act as an access bridge across the spillway to accommodate service vehicles and equipment.

Conventional jointing has been incorporated into the designs to allow for articulation should differential foundation movement occur. The proposed chute and stilling basin sections consist of cantilever side walls and interior floor slabs articulated from the walls. In the lower chute and basin areas, concrete thicknesses have been increased to withstand the large dynamic forces and ensure stability.

d) Foundation and Drainage

Extra deep upstream and downstream cutoff walls and intermediate cross-walls are provided to control foundation seepage.

Where foundations in the region of the crest section are fissured or pervious, additional seepage control will be necessary through drainage conduits and relief wells. For the chute and stilling basin sections a deep granular bedding layer is proposed for the purposes of seepage and uplift pressure control. In the chute area, seepage through the foundation will be relieved by means of pipe drains located directly under the slab with gravity outlets to drainage conduits located parallel to and outside the retaining walls. In the basin area where substantially greater hydrostatic uplift forces are possible a curtain wall and pressure relief pipes connected to the subfloor drainage system are proposed to control uplift pressures.

4.3 Low Level Irrigation Conduits

Irrigation conduits would consist of precast concrete pipelines with a reinforced concrete inlet, gatewell and outlet structures. Flow in the conduit will be controlled by means of sluice gates installed in the gatewell. The gatewell, located just upstream of the dam centreline will be a two-celled structure equipped with both service and auxiliary gates complete with hoisting equipment.

Details of these conduits, including basic dimensions, are shown in Drawings C1 and C2 and Tables C2 and C4.

To ensure maximized live storage, irrigation conduits have been designed for the required release of 300 cfs at minimum reservoir levels, assuming full pipe flow with outlet control. Outlet structures will be hydraulic jump basins designed to handle the full gate, maximum head condition. Gate shafts will be equipped with air supply piping to prevent gate cavitation. Conduit gradients have been set to minimize slug flow or other adverse hydraulic action.

Conduits have been located in the south abutment of the river valley, excavated to some depth into the floodplain material to ensure that structure foundation pads rest firmly on competent bedrock. To compensate for the relatively deep-set conduit a short drop inlet riser is proposed for intake purposes.

Conduits will also be utilized for construction diversion purposes and be converted to permanent irrigation works at completion of the project.

5.0 Basis of Costing

Detailed cost estimates for the proposed works can be found in Tables C1 and C3. These estimates are intended to include all costs associated with construction of the dam embankments and ancillary works, including contingencies. Allowances for engineering, design and surveys have also been included. However, interest during construction and annual charges have been omitted.

Unit prices utilized in the preparation of cost estimates for this study are based on bid prices from recent tenders on similar storage projects, as well as current tender prices on major irrigation works, in Southern Alberta.

The intended scope and/or coverage of specific items which appear in the detailed cost estimate tables are as follows:

1. Mobilization - is assumed to cover initial negotiations with sub-contractors, acquisition of rights to borrow sources, provision of construction facilities and a construction camp.

2. Care of Water - is assumed to cover the cost of miscellaneous works for dewatering the site area during construction, including the cost of major items for river diversion such as additional conduits and cofferdams.

3. Excavations - are assumed to cover all costs necessary to excavate and haul material from its source to place of deposition. Costs include such work as stripping, trimming, ripping, etc.

4. Embankments - are assumed to cover all costs necessary to place and compact material in the embankment or backfill areas. Costs include allowances for mixing material, adding, moisture, etc.

5. Embankment Filter and Drainage System - is assumed to cover all costs necessary to supply and place downstream filter and drainage systems including perforated pipes and relief wells.

6. Rock Riprap - is assumed to cover all costs necessary to harvest, process, haul and place riprap.

7. Granular Blanket Below Riprap - is assumed to cover all costs necessary to excavate, process, haul and place materials on the embankment.

8. Shotcrete Abutment Treatment - is assumed to cover all costs necessary to prepare the abutment adjacent to the impervious clay core, including shotcreting.

9. Concrete Items - are assumed to cover all costs necessary to produce and place concrete as shown on the drawings. Costs include the supply and placement of reinforcement steel and formwork, processing of aggregates and finishing.

10. Spillway Drainage System - is assumed to include all costs associated with the subfloor drainage system under the spillway chute and stilling basin and the conduit outlet basin.

11. Gate Items - are assumed to cover all costs necessary to manufacture and install complete working gates including hoisting systems.

12. Miscellaneous Items - are assumed to cover items which are anticipated at this time as being required, but which are too small or too detailed to include in the cost table.

13. Contingencies - are assumed to cover items of unknown or extra work which cannot be anticipted at this time because of the preliminary nature of the study and the lack of detailed background or field information. It will be observed that a 25 percent contingency allowance was used for this investigation because of the potential problems at this site (only a 20 percent contingency allowance was used for the feasibility level evaluation of Site 7B-1).

TABLE C1
DETAILED COST ESTIMATE
LITTLE BOW SITE 7A - 61700 DAM3 (50,000 AC.FT.)

	QUANTITY	UNIT $	EXTENSION
MOBILIZATION	lump sum	SUBTOTAL	100,000
CARE OF WATER	lump sum	SUBTOTAL	242,000
EMBANKMENT			
Foundation Preparation			
-Stripping	21,255 M3	1.65	35,000
-Key Trench Excavation	152,788 M3	3.00	458,000
-Foundation Over Excavation	45,255 M3	3.00	136,000
Compacted Embankment			
- Zone #1	942,973 M3	0.70	660,000
- Zone #2	158,920 M3	0.70	111,000
Borrow Excavation	1,219,032 M3	1.50	1,829,000
Overhaul	2,250,000 M3KM	0.60	1,350,000
Embankment Filter and Drainage System			
- Zone #4	43,675 M3	21.00	917,000
- Filter Cloth	39,506 M2	1.65	65,000
- Relief Wells	lump sum		150,000
Rock Riprap	21,601 M3	35.00	756,000
Riprap Bedding	18,000 M3	16.00	288,000
Topsoil D/S Face Of Dam	8,278 M3	1.65	14,000
SUBTOTAL EMBANKMENT			6,769,000
SPILLWAY			
Liner(approach channel)	lump sum		425,000
Excavation and Haul	207,504 M3	2.25	467,000
Zone #1 Backfill	8,400 M3	3.90	33,000
Reinforced Concrete	1,658 M3	525.00	870,000
Drainage System	lump sum		45,000
Radial Gates & Hoists(3 sets)	lump sum		108,000
Miscellaneous Items			97,000
SUBTOTAL SPILLWAY			2,045,000
IRRIGATION CONDUIT			
Excavation - Structural	7,700 M3	3.00	23,000
Inlet and Outlet Channel Excavation	4,600 M3	3.00	14,000
Zone #1 Backfill	7,700 M3	3.90	30,000
Precast Concrete Pipe	175 M	1250.00	219,000
Structural Concrete	358 M3	785.00	281,000
Control Gates & Hoists(2 sets)	lump sum		70,000
Miscellaneous Items			32,000
SUBTOTAL CONDUIT			$669,000
SUBTOTAL CONSTRUCTION			$9,825,000
Contingencies(25%)			$2,456,000
TOTAL CONSTRUCTION COST			$12,281,000

TABLE C2
Pertinent Data
Little Bow Site 7A
61 700 dam^3 (50,000 ac.ft.) Storage Alternative

Reservoir

Full Supply Level (FSL)	958.6 m
Capacity at FSL	61 700 dam^3
Live Storage	58 200 dam^3
Flooded Area at FSL	770 ha
Maximum Depth at FSL	19.6 m
Project Design Flood - 0.5 PMF (inflow)	322.8 m^3/s
Spillway Design Flood - 1:100 (inflow)	147.3 m^3/s
Maximum Water Level	961.3 m

Embankment

Top of Dam Elevation	961.6 m
Freeboard	3.0 m
Crest Length	840 m
Maximum Height	24.6 m
Volume of Fill	1 102 000 m^3
Freeboard at Spillway Design Flood	2.6 m
Freeboard at Project Design Flood	0.3 m

Spillway

Crest Elevation	956.5 m
Radial Gates	3 @ 3.5 m (W) x 2.1 m (H)
Net Weir Length	10.5 m
Gross Crest Width	11.3 m
Chute Width	varies 11.3 m to 16.5 m
Basin Width	16.5 m
Structure Length	103.0 m
Basin Elevation	935.4 m
Design Discharge (1:100 routed outflow)	84.6 m^3/s
Probable Maximum Discharge (0.5 PMF routed outflow)	239.2 m^3/s

Irrigation Supply Conduit

Conduit Diameter	1.5 m
Conduit Length	175 m
Irrigation Supply Capacity Requirement	8.5 m^3/s
Gate Size	2 @ 2 m x 2 m
Intake Crest Elevation	942.5 m
Basin Elevation	935.4 m
Minimum Reservoir Elevation to Pass Irrigation Requirement	943.2 m

TABLE C3
DETAILED COST ESTIMATE
LITTLE BOW SITE 7A - 86300 DAM3 (70,000 AC.FT.)

	QUANTITY	UNIT $	EXTENSION
MOBILIZATION	lump sum	SUBTOTAL	100,000
CARE OF WATER	lump sum	SUBTOTAL	295,000
EMBANKMENT			
Foundation Preparation			
-Stripping	27,030 M3	1.65	45,000
-Key Trench Excavation	175,588 M3	3.00	527,000
-Foundation Over Excavation	73,845 M3	3.00	222,000
Compacted Embankment			
- Zone #1	1,178,850 M3	0.70	825,000
- Zone #2	222,634 M3	0.70	156,000
Borrow Excavation	1,687,451 M3	1.50	2,531,000
Overhaul	2,800,000 M3KM	0.60	1,680,000
Embankment Filter and Drainage System			
- Zone #4	48,775 M3	21.00	1,024,000
- Filter Cloth	50,389 M2	1.65	83,000
- Relief Wells	lump sum		150,000
Rock Riprap	27,909 M3	35.00	977,000
Riprap Bedding	23,257 M3	16.00	372,000
Topsoil D/S Face Of Dam	10,695 M3	1.65	18,000
SUBTOTAL EMBANKMENT			8,610,000
SPILLWAY			
Liner(approach channel)	lump sum		325,000
Excavation and Haul	133,256 M3	2.25	300,000
Zone #1 Backfill	8,800 M3	3.90	34,000
Reinforced Concrete	1,697 M3	525.00	891,000
Drainage System	lump sum		50,000
Radial Gates & Hoists(3 sets)	lump sum		99,000
Miscellaneous Items			85,000
SUBTOTAL SPILLWAY			1,784,000
IRRIGATION CONDUIT			
Excavation - Structural	8,580 M3	3.00	26,000
Inlet and Outlet Channel Excavation	4,600 M3	3.00	14,000
Zone #1 Backfill	8,580 M3	3.90	33,000
Precast Concrete Pipe	195 M	1250.00	244,000
Structural Concrete	383 M3	785.00	301,000
Control Gates & Hoists(2 sets)	lump sum		80,000
Miscellaneous Items			35,000
SUBTOTAL CONDUIT			$733,000
SUBTOTAL CONSTRUCTION			$11,522,000
Contingencies(25%)			$2,880,000
TOTAL CONSTRUCTION COST			$14,402,000

TABLE C4
Pertinent Data
Little Bow Site 7A
86 300 dam^3 (70,000 ac.ft.) Storage Alternative

Reservoir

Full Supply Level (FSL)	961.5 m
Capacity at FSL	86 300 dam^3
Live Storage	82 800 dam^3
Flooded Area at FSL	1,000 ha
Maximum Depth at FSL	22.5 m
Project Design Flood - 0.5 PMF (inflow)	322.8 m^3/s
Spillway Design Flood - 1:100 (inflow)	147.3 m^3/s
Maximum Water Level	964.3 m

Embankment

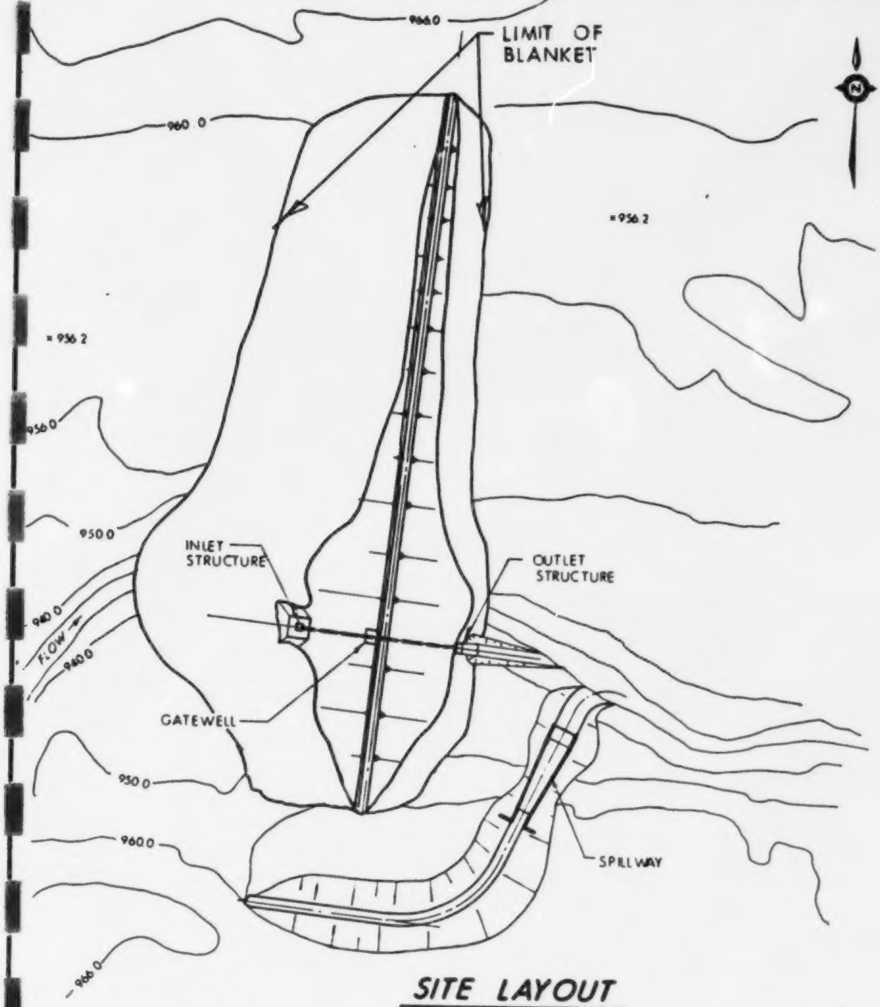
Top of Dam Elevation	964.6 m
Freeboard	3.1 m
Crest Length	880 m
Maximum Height	27.6 m
Volume of Fill	1 401 000 m^3
Freeboard at Spillway Design Flood	2.7 m
Freeboard at Project Design Flood	0.3 m

Spillway

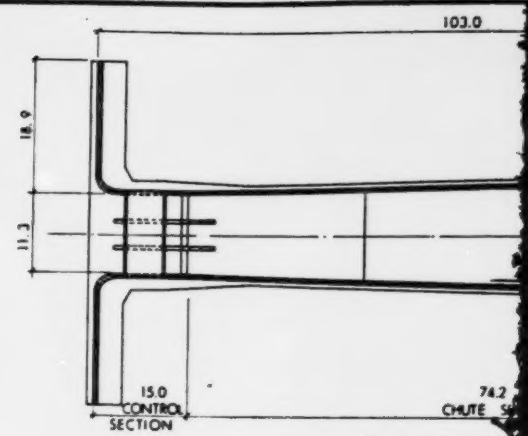
Crest Elevation	959.4 m
Radial Gates	3 @ 3.3 m (W) x 2.1 m (H)
Net Weir Length	9.9 m
Gross Crest Width	10.7 m
Chute Width	varies 10.7 m to 16.0 m
Basin Width	16.0 m
Structure Length	116.0 m
Basin Elevation	935.3 m
Design Discharge (1:100 routed outflow)	78.6 m^3/s
Probable Maximum Discharge (0.5 PMF routed outflow)	228.9 m^3/s

Irrigation Supply Conduit

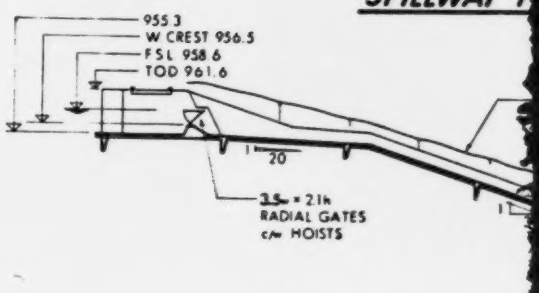
Conduit Diameter	1.5 m
Conduit Length	195 m
Irrigation Supply Capacity Requirement	8.5 m^3/s
Gate Size	2 @ 2 m x 2 m
Intake Crest Elevation	942.5 m
Basin Elevation	935.4 m
Minimum Reservoir Elevation to Pass Irrigation Requirement	943.2 m


966.0
LIMIT OF BLANKET
960.0
× 956.2
× 956.2
956.0
950.0
INLET STRUCTURE
OUTLET STRUCTURE
940.0
FLOW
940.0
GATEWELL
950.0
960.0
SPILLWAY
966.0

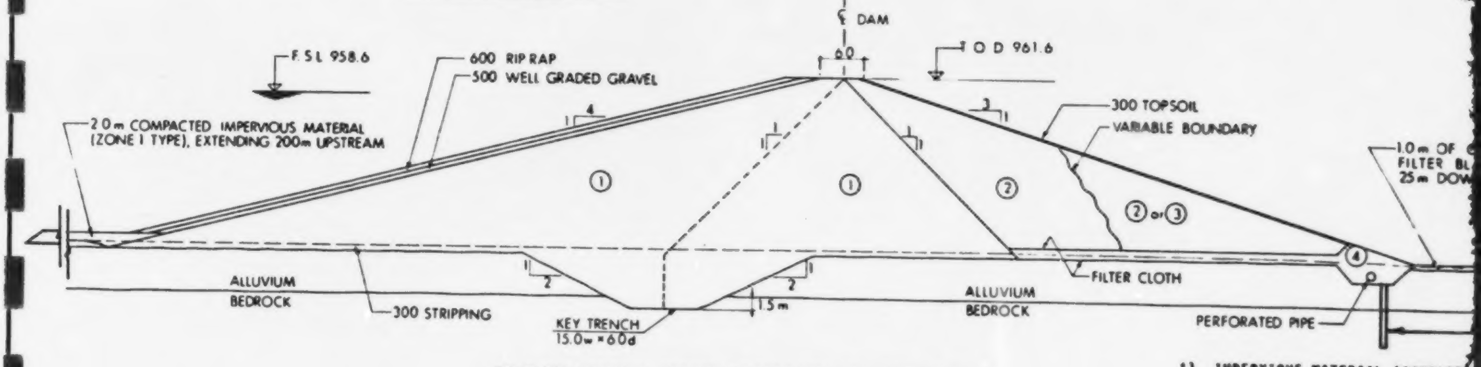
SITE LAYOUT


103.0
18.9
11.3
15.0
CONTROL SECTION
74.2
CHUTE S

SPILLWAY


955.3
W CREST 956.5
FSL 958.6
TOD 961.6
1 20
3.5w × 2.1h
RADIAL GATES
c/w HOISTS

℄ SECTION SPILL


℄ DAM
6.0
F.S.L 958.6
600 RIP RAP
500 WELL GRADED GRAVEL
T O D 961.6
4
1
3
1
300 TOPSOIL
VARIABLE BOUNDARY
2.0m COMPACTED IMPERVIOUS MATERIAL (ZONE 1 TYPE), EXTENDING 200m UPSTREAM
①
①
②
② or ③
1.0m OF
FILTER BL
25m DOW
④
FILTER CLOTH
1
2
2
1
ALLUVIUM
BEDROCK
300 STRIPPING
KEY TRENCH
15.0w × 6.0d
1.5m
ALLUVIUM
BEDROCK
PERFORATED PIPE

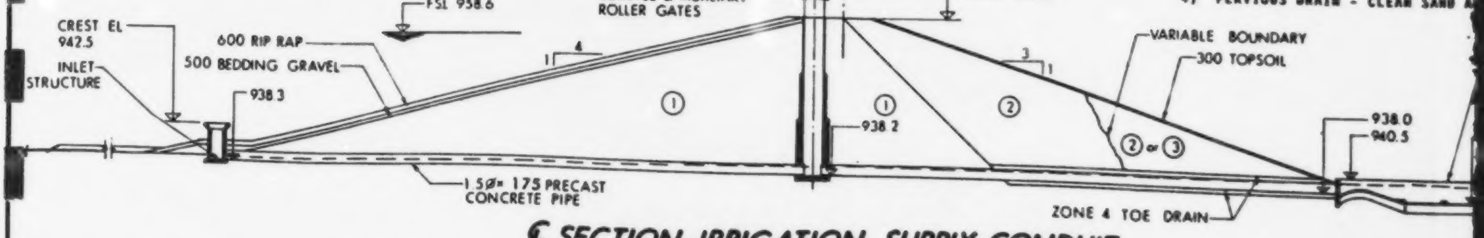
MAXIMUM EMBANKMENT SECTION

1) IMPERVIOUS MATERIAL (COMPACTE
UPLANDS)

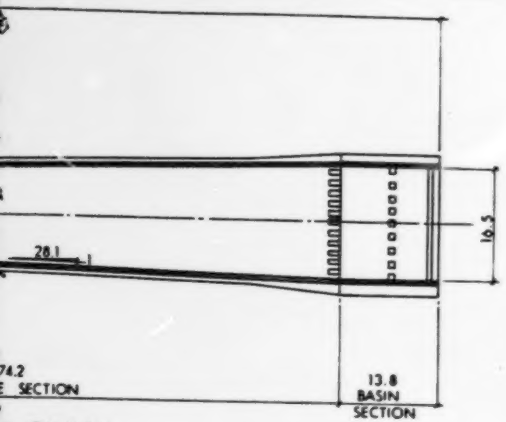
2) PERVIOUS TO SEMI-PERVIOUS MATE
EXCAVATION AND BORROW AREAS I

3) PERVIOUS TO SEMI-PERVIOUS REC
+ SHALE (FROM SPILLWAY EXCAVA

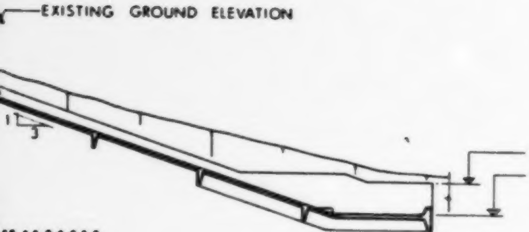
4) PERVIOUS DRAIN - CLEAN SAND A


3.0 × 3.0 CONC. WETWELL EQUIPPED WITH 2.0 × 2.0 SERVICE & AUXLIARY ROLLER GATES
FSL 958.6
TOD 961.6
CREST EL 942.5
600 RIP RAP
500 BEDDING GRAVEL
INLET STRUCTURE
938.3
4
1
3
1
VARIABLE BOUNDARY
300 TOPSOIL
①
①
②
② or ③
938.2
938.0
940.5
1.5Ø × 175 PRECAST CONCRETE PIPE
ZONE 4 TOE DRAIN

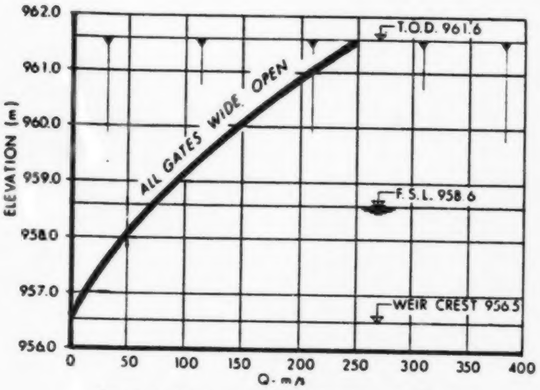
℄ SECTION-IRRIGATION SUPPLY CONDUIT AND DIVERSION WORKS


28.1
16.5
74.2
E SECTION
13.8
BASIN
SECTION

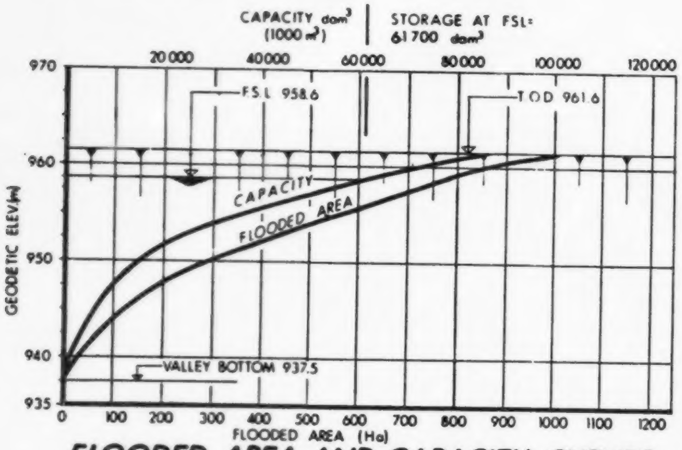
Y PLAN


EXISTING GROUND ELEVATION
1
3
940.2
935.4

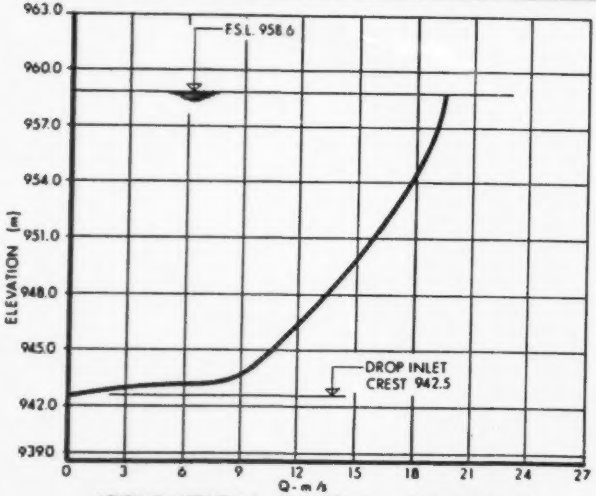
ILLWAY



SPILLWAY RATING CURVE



FLOODED AREA AND CAPACITY CURVES



IRRIGATION SUPPLY CONDUIT RATING CURVE

OF GRAVEL REVERSE
R BLANKET, EXTENDING
DOWNSTREAM

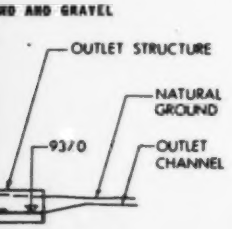
RELIEF WELLS

ACTED SILTY CLAY FROM

MATERIAL (FROM CUTOFF
AS IN ALLUVIUM)

RECOMPACTED SANDSTONE
CAVATION)

ND AND GRAVEL


OUTLET STRUCTURE
NATURAL GROUND
937.0
OUTLET CHANNEL

REV.	DATE	REVISION DESCRIPTION	ENG.	APPR.
	Mos86	FEASIBILITY DESIGN		RC.

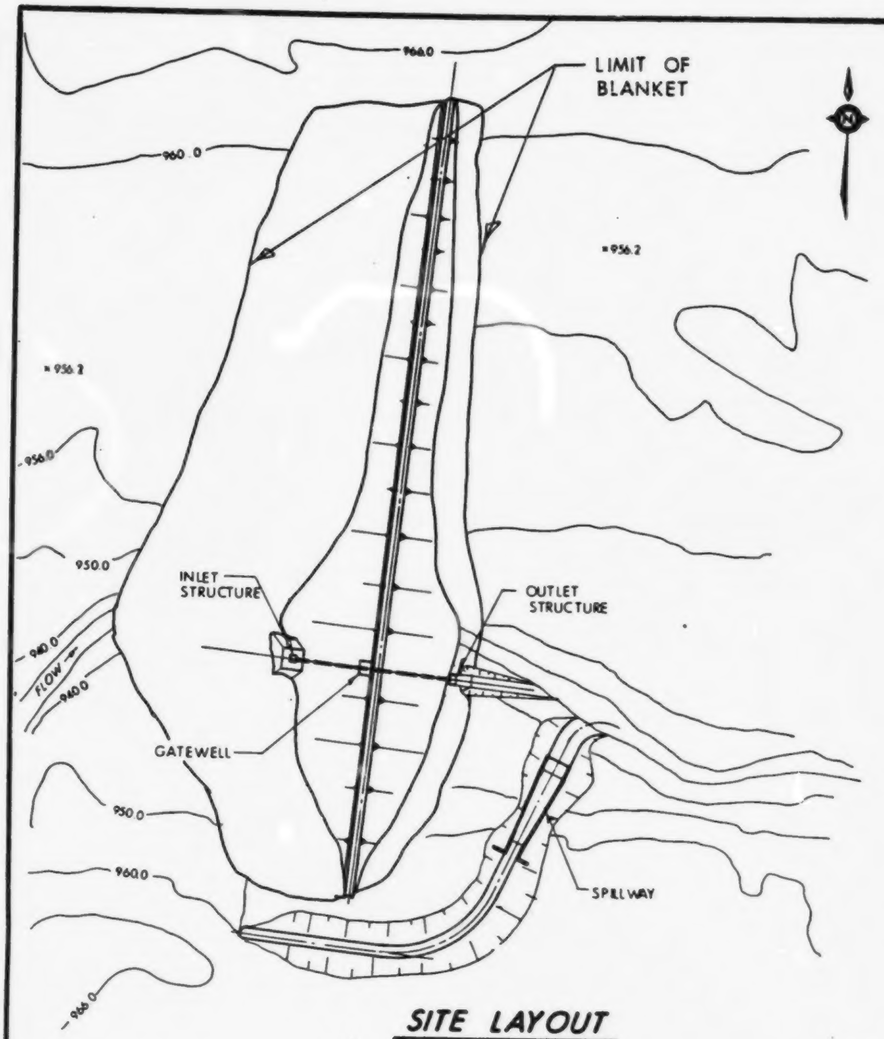
W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT
LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
SITE 7A
FEASIBILITY DESIGNS

61700 dam³ STORAGE ALTERNATIVE
(50,000 ac.ft)

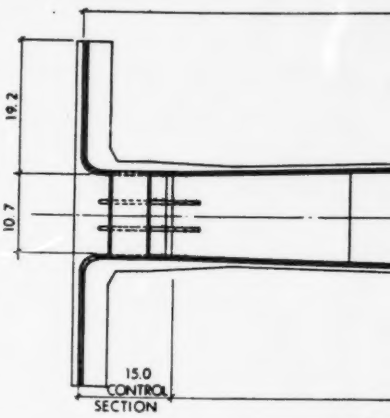
GENERAL LAYOUT

DESIGNED	CHECKED	DATE	JOB No.	DRAWING No.
		14-03-86		
DRAFTED L.N.	APPROVED	SCALE NTS	SHEET No. 1 of 2	C1



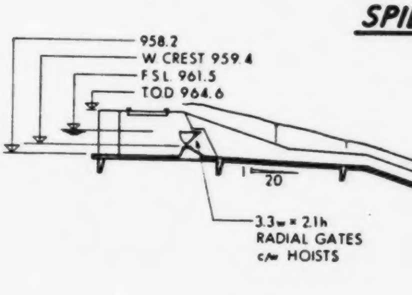
966.0
LIMIT OF BLANKET
960.0
956.2
956.2
956.0
950.0
INLET STRUCTURE
OUTLET STRUCTURE
940.0
FLOW
940.0
GATEWELL
950.0
960.0
SPILLWAY
966.0
N

SITE LAYOUT



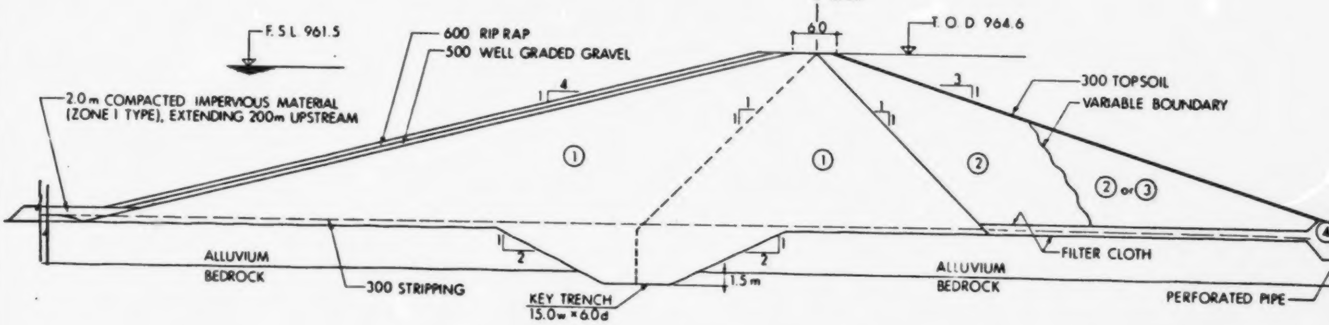
19.2
10.7
15.0
CONTROL SECTION

SPI



958.2
W CREST 959.4
FSL 961.5
TOD 964.6
1
20
3.3w × 2.1h
RADIAL GATES
c/w HOISTS

℄ SECTIO



℄ DAM
6.0
F.S.L. 961.5
T.O.D. 964.6
600 RIP RAP
500 WELL GRADED GRAVEL
2.0m COMPACTED IMPERVIOUS MATERIAL (ZONE I TYPE), EXTENDING 200m UPSTREAM
1
4
1
1
1
1
3
1
300 TOPSOIL
VARIABLE BOUNDARY
①
①
②
② or ③
1
2
2
1
ALLUVIUM
BEDROCK
300 STRIPPING
KEY TRENCH 15.0w × 6.0d
1.5m
ALLUVIUM
BEDROCK
FILTER CLOTH
PERFORATED PIPE

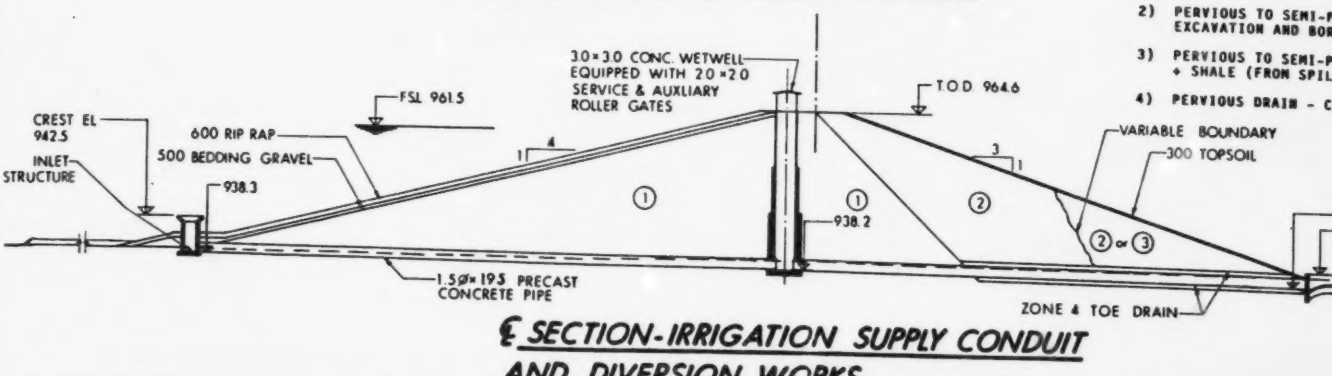
MAXIMUM EMBANKMENT SECTION

1) IMPERVIOUS MATERIA
UPLANDS)

2) PERVIOUS TO SEMI-P
EXCAVATION AND BOR

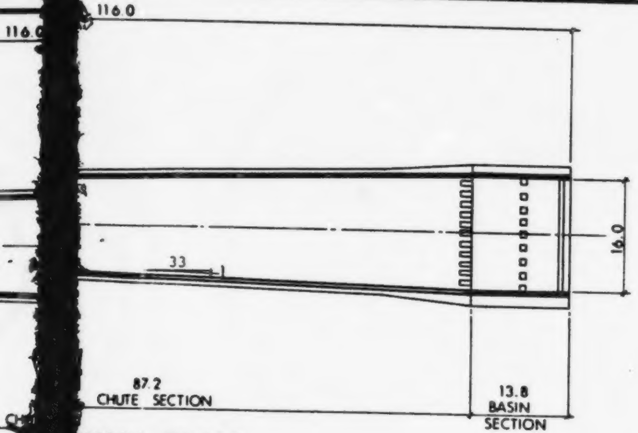
3) PERVIOUS TO SEMI-P
+ SHALE (FROM SPIL

4) PERVIOUS DRAIN - C

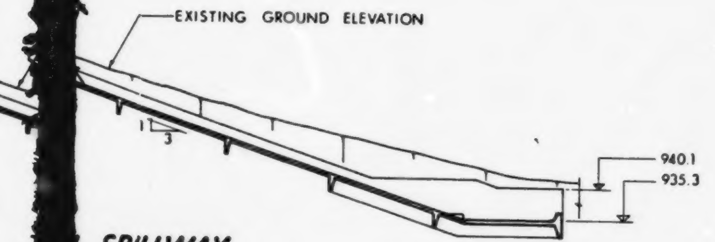


3.0 × 3.0 CONC. WETWELL EQUIPPED WITH 2.0 × 2.0 SERVICE & AUXLIARY ROLLER GATES
FSL 961.5
T.O.D. 964.6
CREST EL 942.5
600 RIP RAP
500 BEDDING GRAVEL
INLET STRUCTURE
938.3
1
4
3
1
①
①
②
② or ③
938.2
VARIABLE BOUNDARY
300 TOPSOIL
1.5Ø × 195 PRECAST CONCRETE PIPE
ZONE 4 TOE DRAIN

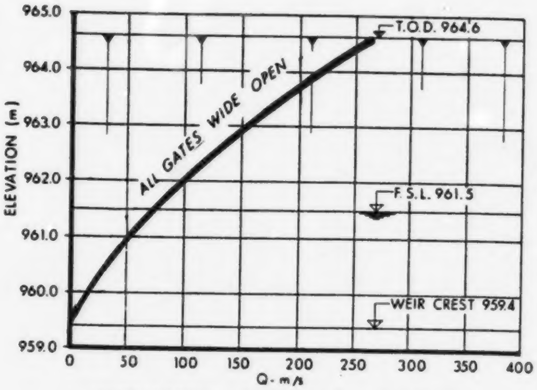
℄ SECTION-IRRIGATION SUPPLY CONDUIT AND DIVERSION WORKS


116.0
116.0
33
1
16.0
87.2
CHUTE SECTION
13.8
BASIN
SECTION

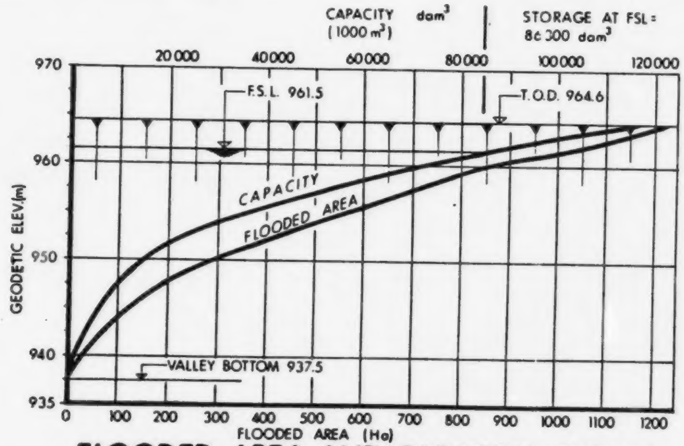
WAY PLAN


EXISTING GROUND ELEVATION
1
3
940.1
935.3

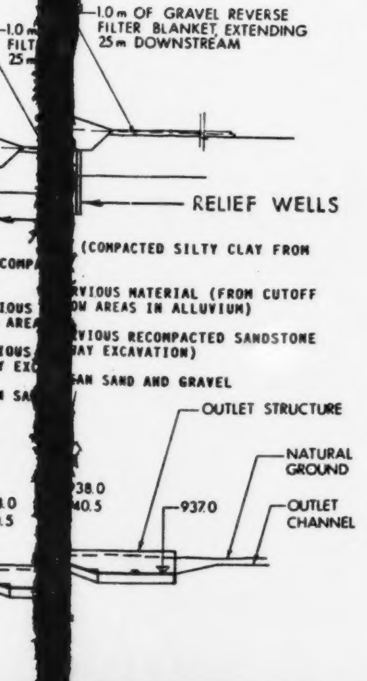
SPILLWAY

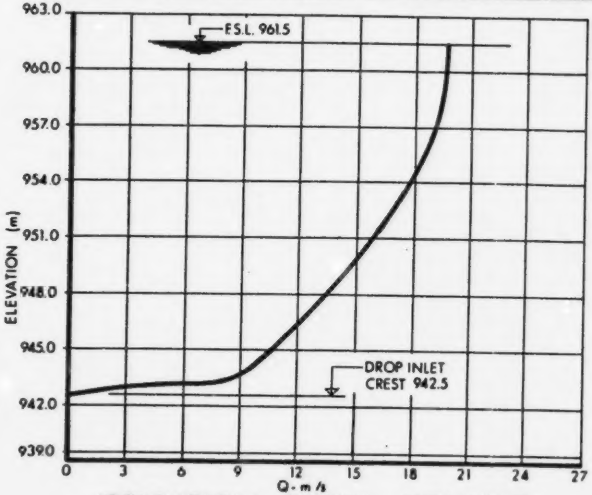


SPILLWAY RATING CURVE



FLOODED AREA AND CAPACITY CURVES


1.0 m OF GRAVEL REVERSE FILTER BLANKET EXTENDING 25 m DOWNSTREAM
1.0 m
FILT
25 m
RELIEF WELLS
COMPA
(COMPACTED SILTY CLAY FROM
IOUS
AREA
RVIOUS MATERIAL (FROM CUTOFF
OW AREAS IN ALLUVIUM)
IOUS
Y EXC
RVIOUS RECOMPACTED SANDSTONE
AY EXCAVATION)
N SA
AN SAND AND GRAVEL
OUTLET STRUCTURE
NATURAL GROUND
938.0
940.5
.0
.5
937.0
OUTLET CHANNEL



IRRIGATION SUPPLY CONDUIT
RATING CURVE

REV.	DATE	REVISION DESCRIPTION	ENG.	APPR.
	14-03-86	FEASIBILITY DESIGN		P.C.

W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT
LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
SITE 7A
FEASIBILITY DESIGNS

86300 dam³ STORAGE ALTERNATIVE
(70,000 ac.ft)

GENERAL LAYOUT

DESIGNED	CHECKED	DATE 14-03-86	JOB No.	DRAWING No.
DRAFTED L.N.	APPROVED	SCALE NTS.	SHEET No. 2 of 2	C2

LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
SITE 7A
FEASIBILITY DESIGN REPORT
March, 1986

APPENDIX D

RESERVOIR COSTS

TABLE OF CONTENTS

Page No.

1.0 BASIS OF RESERVOIR COSTING D-1
    1.1 Land Acquisition D-1
    1.2 Reservoir Costs D-1

2.0 LITTLE BOW SITE 7A, 61 700 dam^3 (50,000 ac.ft)

    2.1 Land Acquisition D-2
    2.2 Reservoir Costs D-2
        2.2.1 Roads and Bridges D-2
        2.2.2 Farm Buildings D-3
        2.2.3 Utilities D-4

3.0 LITTLE BOW SITE 7A, 86 300 dam^3 (70,000 ac.ft)

    3.1 Land Acquisition D-6
    3.2 Reservoir Costs D-6
        3.2.1 Roads and Bridges D-6
        3.2.2 Farm Buildings D-7
        3.2.3 Utilities D-7

LIST OF TABLES

Title		Table No.
Reservoir Costs	- Little Bow Site 7A - 61 700 dam^3 (50,000 ac.ft.)	D1
Reservoir Costs	- Little Bow Site 7A - 86 300 dam^3 (70,000 ac.ft.)	D2

LIST OF DRAWINGS

Title	Drawing No.
Little Bow Site 7A - 61 700 dam^3 (50,000 ac.ft.)	D1
Little Bow Site 7A - 86 300 dam^3 (70,000 ac.ft.)	D2

LIST OF FIGURES

Title	Figure No.
Layout of Reservoir Crossings	D1

1.0 BASIS OF RESERVOIR COSTS

An estimate of the costs associated with land acquisition and reservoir costs at Site 7A has been prepared, as detailed in subsequent sections of this appendix. Location plans of reservoir damages are shown on Figures D1 and D2.

1.1 Land Acquisition

The areas of land required for the two reservoirs were based on top-of-dam elevation to allow for reservoir surcharge during river flood stages and for possible future erosion of the reservoir slopes. The total reservoir areas were broken down into cultivation (including hay flats) and other land use (pasture, bush, river) as based on field inspections and air photo studies in conjunction with topographic plans of the reservoir. Unit land costs of $1980 per hectare (ha) of cultivation and $740 per hectare of other lands as used in previous reports (References 1 and 2) have been discussed with officials from the Municipal District of Foothills and are considered to be representative of current land values in this area. An additional allowance of 25% for serverance and acquisition cost has been included.

1.2 Reservoir Costs

Costs associated with the reservoirs included in this phase of the study include the following:

- roads and bridges
- power transmission lines
- telephone lines
- natural gas lines
- farm buildings
- water intake system

The costs associated with public utilities were estimated based on information supplied by Trans-Alta Utilities Corporation, Canadian Western Natural Gas Company Limited, and Alberta Government Telephones.

The costs associated with relocation of existing farm buildings affected by the reservoir were based generally on costs supplied by local moving companies in connection with a study of Keho Lake Enlargement (1980), updated to 1985.

The costs of raising existing roads and bridges were calculated separately for each road.

2.0 LITTLE BOW SITE 7A - 61 700 DAM^3 (50,000 AC.FT.)

2.1 Land Acquisition

The total area of land affected by the reservoir to top-of-dam elevation is 1 005 ha, of which 315 ha are cultivated as tame hay flats and cropland. The costs of acquisition are estimated as follows:

Cultivation	315 ha @ $1980	=	$ 624,000
Other	690 ha @ $ 740	=	511,000
Severance (25%)		=	284,000
	TOTAL		$1,419,000

2.2 Reservoir Costs

2.2.1 Roads and Bridges

a) SE 5-15-25-W4

This existing road and bridge would be flooded by the Site 7A reservoir. Traffic can be re-routed on existing roads at no additional cost.

b) Secondary Highway (S.H.) 529

Secondary Highway 529 crosses the Site 7A reservoir at the north boundary of Section 12-15-26-W4. It is assumed that the current alignment of the road would be retained and the existing road and bridge raised to form a causeway at an estimated cost of $3,000,000. A profile and section of the proposed causeway is shown on Figure D1.

c) SE 26-15-26-W4 (Allston Crossing)

Retaining this crossing would involve raising the existing road and bridge at an estimated cost of $1,000,000. A profile and section of the proposed crossing is shown in Figure D1.

2.2.2 Farm Buildings

a) NE 31-14-25-W4

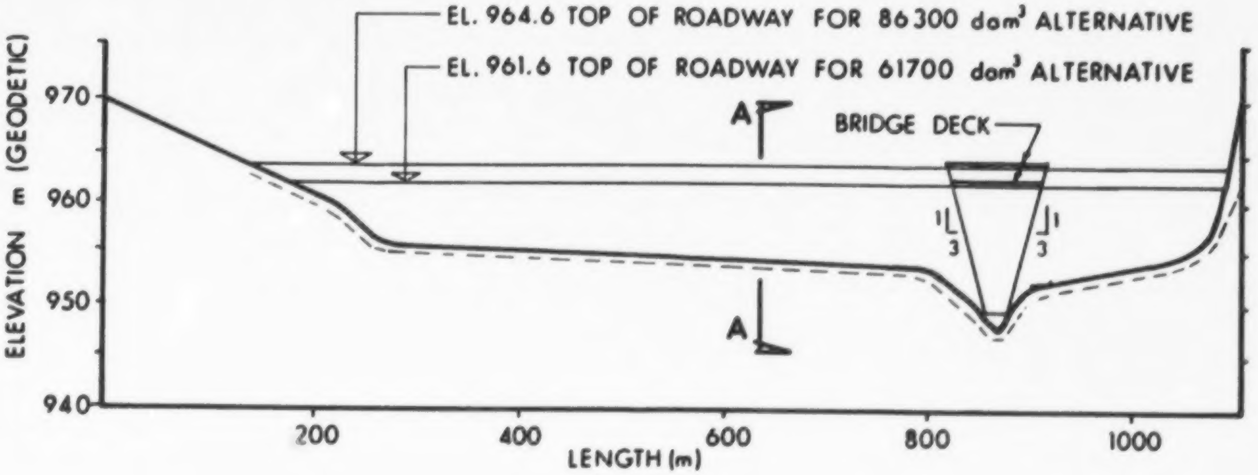
The relocation of this occupied farmstead is estimated at $70,000.

b) NE 12-15-26-W4

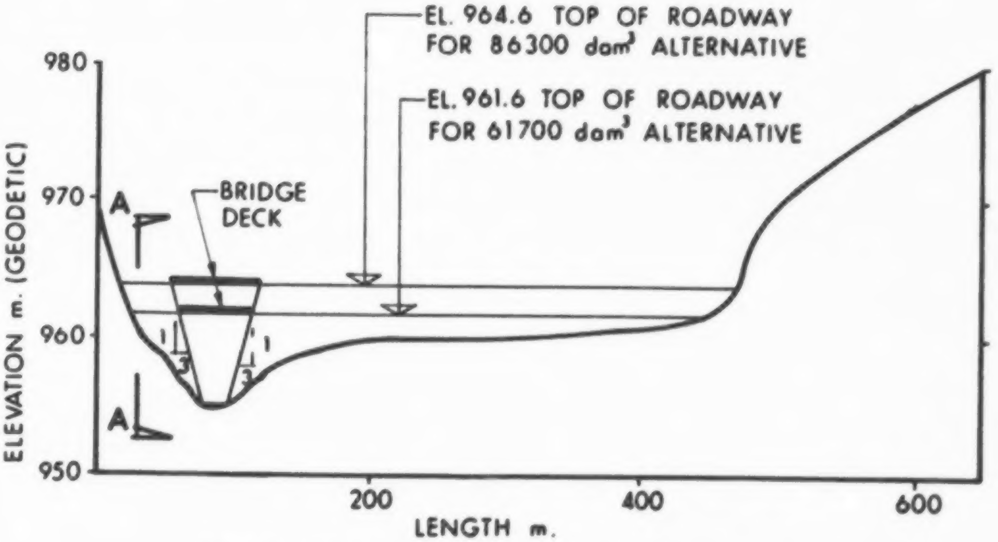
The relocation of this occupied farmstead is estimated at $80,000.

c) Hutterite Colony SE 13-15-26-W4

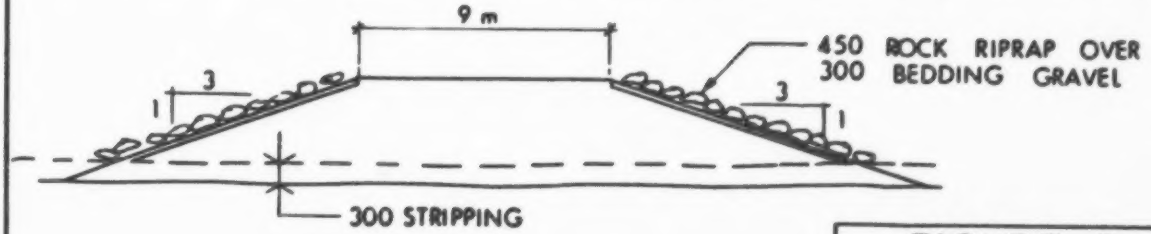
The Little Bow River Hutterite Colony consists of a large number of buildings, some of which would have to be dismantled and re-constructed. The costs of dismantling and re-


EL. 964.6 TOP OF ROADWAY FOR 86300 dam³ ALTERNATIVE
EL. 961.6 TOP OF ROADWAY FOR 61700 dam³ ALTERNATIVE
A
BRIDGE DECK
1
3
1
3
A
ELEVATION m (GEODETIC)
970
960
950
940
200
400
600
800
1000
LENGTH (m)

ROAD CROSSING AT HIGHWAY 529
(NORTH BOUNDARY SECTION 12 - 15 - 26 - W4)


EL. 964.6 TOP OF ROADWAY
FOR 86300 dam³ ALTERNATIVE
EL. 961.6 TOP OF ROADWAY
FOR 61700 dam³ ALTERNATIVE
980
970
960
950
A
BRIDGE
DECK
1
3
1
3
A
ELEVATION m. (GEODETIC)
200
400
600
LENGTH m.

ROAD CROSSING AT SOUTH BOUNDARY SECTION 26-15-26-W.4


9 m
3
1
450 ROCK RIPRAP OVER
300 BEDDING GRAVEL
3
1
300 STRIPPING

SECTION A-A

FIGURE D1

LAYOUT OF RESERVOIR CROSSINGS

constructing the major buildings, plus relocation of the smaller structures, including re-connection of utilities are estimated at $1,000,000.

d) SE 26-15-26-W4

Relocation of this occupied farmstead is estimated to cost $80,000.

2.2.3 Utilities

a) Powerlines

i) A three-phase power line on double wooden poles crosses the Little Bow River along the east boundary of Section 31-14-25. Special long span towers are proposed at the top of the valley, at an estimated cost of $200,000.

ii) A TransAlta single-phase line crosses the reservoir in the SE 26-15-26-W4. The line would be relocated at an estimated cost of $70,000.

b) Pipelines

No pipelines were found to be affected by the reservoir with the exception of natural gas service lines to farm buildings which are to be relocated. The cost of these natural gas lines has been included in the farm buildings relocation costs.

c) Town of Vulcan Water Intake and Pumphouse

The town of Vulcan water intake and pumphouse in the NE 35-15-26-W4 would have to be relocated. This would involve construction of a new intake line and pumphouse. Estimated cost of this work is $150,000.

d) Telephone Lines

One short section of telephone line in the SW 18-15-25 would have to be relocated at an estimated cost of $5,000.

TABLE D1
RESERVOIR COSTS
LITTLE BOW SITE 7A
61 700 dam^3 (50,000 ac.ft.)

Land Acquisition	1,419,000
Roads and Bridges	4,000,000
Farmstead Relocations	1,230,000
Utility Relocations	425,000
TOTAL	$7,074,000

3.0 LITTLE BOW SITE 7A - 86 300 DAM^3 (70,000 AC.FT.)

3.1 Land Acquisition

The total area of lands affected by the reservoir to top-of-dam elevation is 1 235 ha, of which approximately 324 ha are cultivated as hay or cropland.

The cost of acquisition is estimated as follows:

Cultivation or Irrigation	324 ha. @ $1980	642,000
Other	911 ha. @ $740	674,000
Severance (25%)		329,000
TOTAL		$1,645,000

3.2 Reservoir Costs

3.2.1 Roads and Bridges

(a) SE 5-15-25-W4

This existing road and bridge would be flooded by the Site 7A reservoir. Traffic can be re-routed on existing roads at no additional cost.

(b) Secondary Highway 529

The current alignment of the road would be retained as per Section 2.2.1 (b) at an estimated cost of $3,900,000.

(c) SE 26-15-26-W4 (Allston Crossing)

The existing road and bridge would be raised as per Section 2.2.1 (c) at an estimated cost of $1,400,000.

3.2.2 Farm Buildings

a) NE 31-14-25-W4

The relocation of this occupied farmstead is estimated at $70,000 (as per Section 2.2.2 (a)).

b) NE 12-15-26-W4

The relocation of this occupied farmstead is estimated at $80,000 (as per Section 2.2.2 (b)).

c) Hutterite Colony SE 13-15-26-W4

Relocation of the Little Bow River Hutterite Colony, as described in Section 2.2.2 (c), is estimated to cost $1,000,000.

d) SE 26-15-26-W4

Relocation of this occupied farmstead is estimated to cost $80,000 (as per Section 2.2.2 (d)).

3.2.3 Utilities

a) Powerlines

i) A three-phase power line, as described in Section 2.2.3 (a) (i), would be adapted at a cost of $200,000.

ii) The small single phase powerline, as described in Section 2.2.3(a) (ii) would be relocated at an estimated cost of $70,000.

b) Pipelines

No pipelines were found to be affected by the reservoir, with the exception of farm services as described in Section 2.2.3 (b).

c) Town of Vulcan Water Intake and Pumphouse

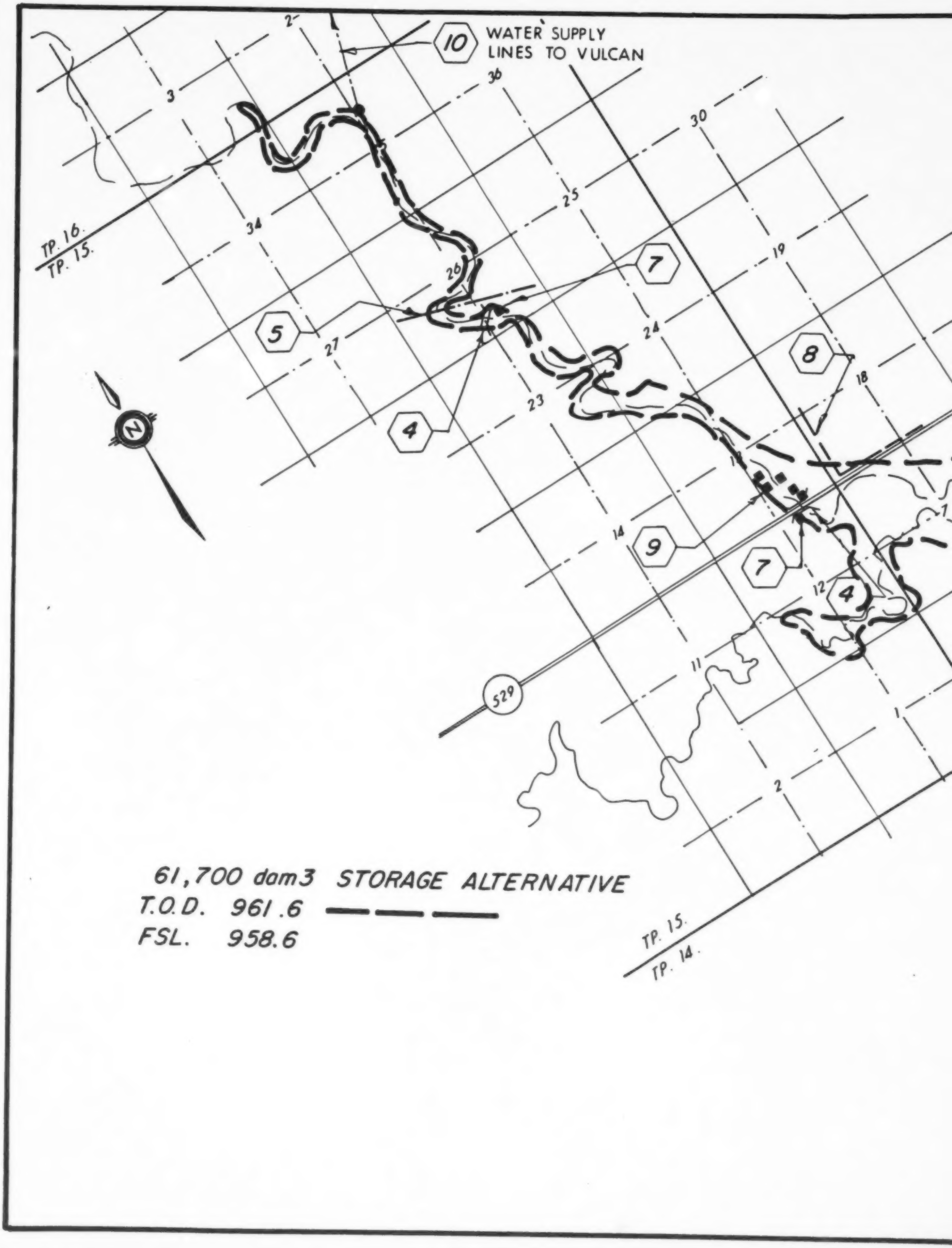
The water intake and pumphouse, as described in Section 2.2.3(c), would be relocated at an estimated cost of $150,000.

d) Telephone Lines

One short section of telephone line in the SW 18-15-25-W4 would have to be relocated at an estimated cost of $5,000 (as per Section 2.2.3 (d)).

TABLE D2
RESERVOIR COSTS
LITTLE BOW SITE 7A
86 300 dam^3 (70,000 ac.ft.)

Land Acquisition	$1,645,000
Roads and Bridges	5,300,000
Farmstead Relocations	1,230,000
Utility Relocations	425,000
TOTAL	$8,600,000

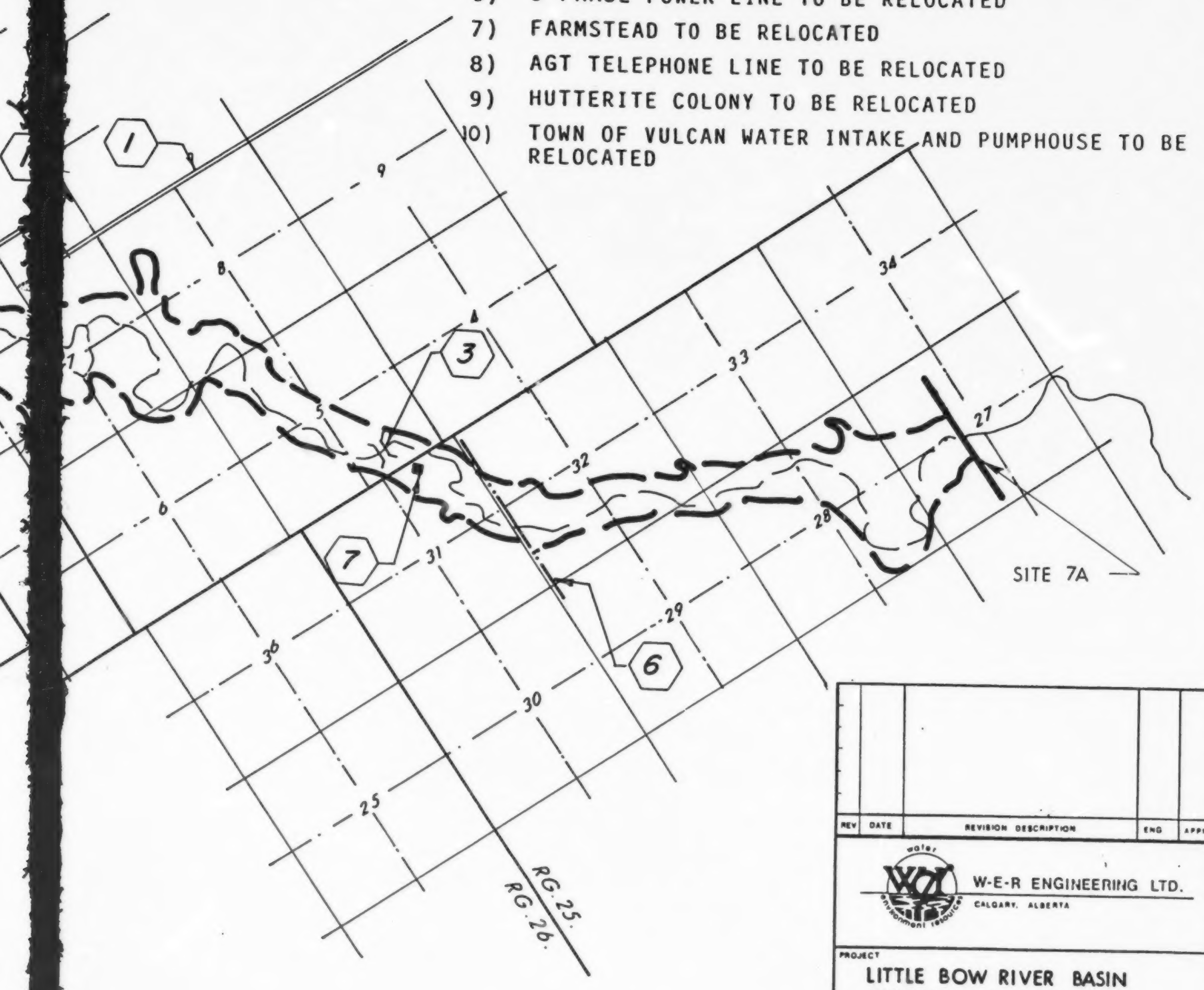


10
WATER SUPPLY LINES TO VULCAN
2
3
36
30
25
34
TP. 16.
TP. 15.
26
19
7
5
27
24
8
18
4
23
14
9
7
12
4
11
529
2
TP. 15.
TP. 14.
N

61,700 dam3 STORAGE ALTERNATIVE
T.O.D. 961.6 ———
FSL. 958.6

SUMMARY OF DAMAGES

1) HIGHWAY NO. 529
3) BRIDGE TO BE ABANDONED
4) BRIDGE TO BE REPLACED
5) SINGLE PHASE POWER LINE TO BE RELOCATED
6) 3 PHASE POWER LINE TO BE RELOCATED
7) FARMSTEAD TO BE RELOCATED
8) AGT TELEPHONE LINE TO BE RELOCATED
9) HUTTERITE COLONY TO BE RELOCATED
10) TOWN OF VULCAN WATER INTAKE AND PUMPHOUSE TO BE RELOCATED



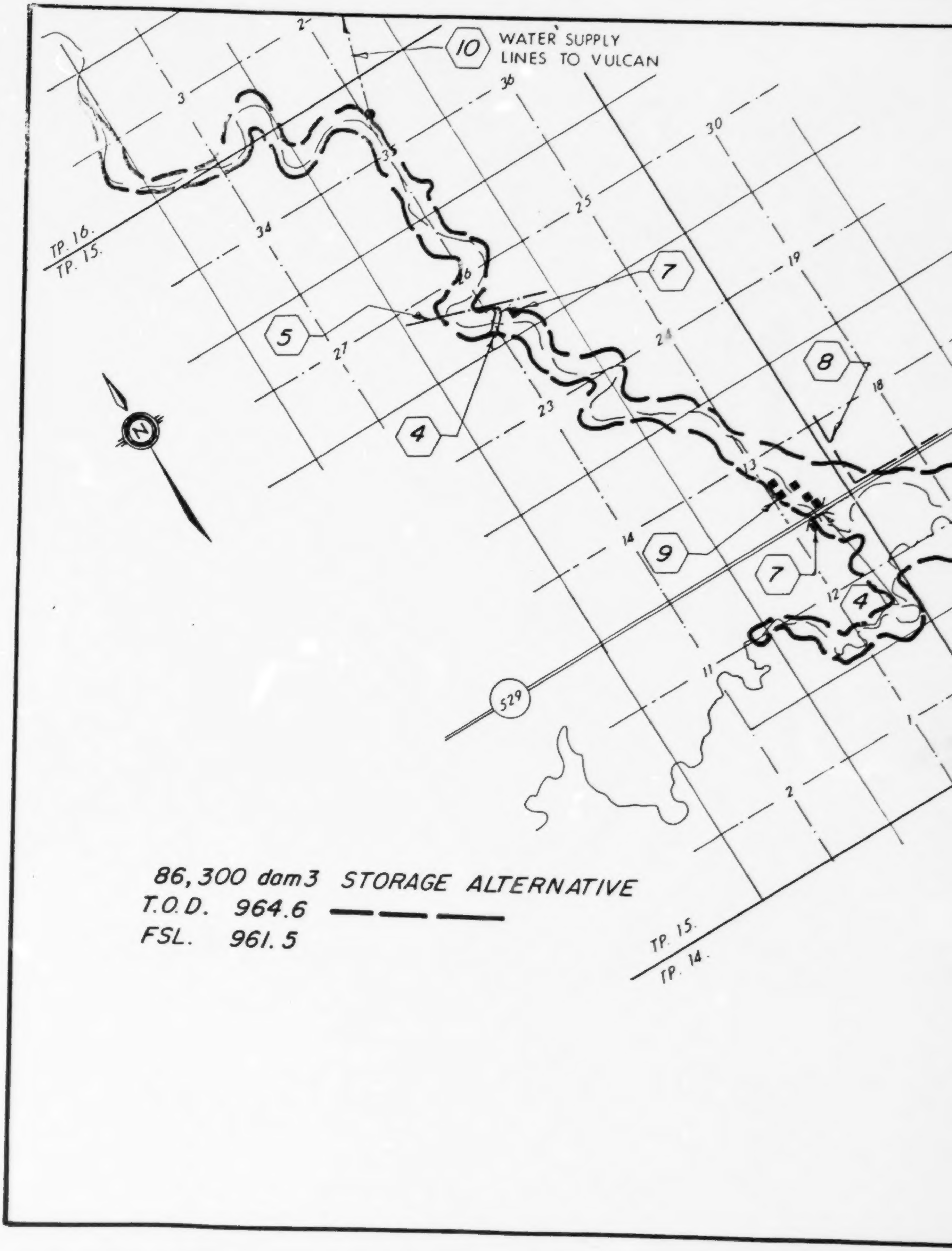
REV	DATE	REVISION DESCRIPTION	ENG	APPR

W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT
LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
SITE 7A FEASIBILITY DESIGN

61,700 dam^3 (50,000 ac.ft.)
STORAGE ALT.
RESERVOIR COSTS
SUMMARY PLAN

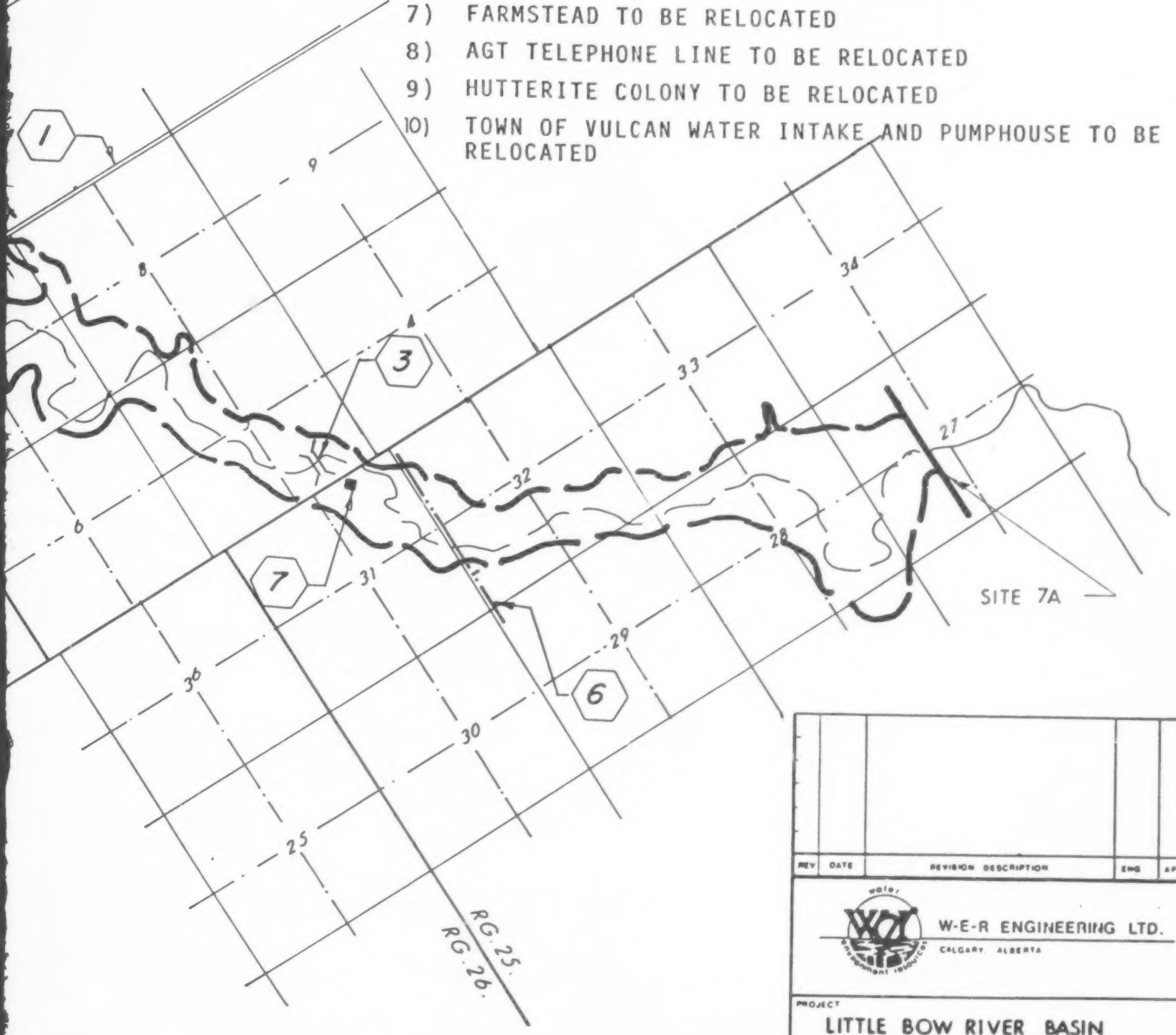
DESIGNED P.B.	CHECKED	DATE 11·05·86	JOB No	DRAWING No D1
DRAFTED	APPROVED	SCALE NTS.	SHEET No	


10
WATER SUPPLY LINES TO VULCAN
TP. 16.
TP. 15.
3
2
36
35
34
30
25
26
27
24
23
19
18
13
14
12
11
1
2
5
7
4
8
9
7
4
529
TP. 15.
TP. 14.
N

86,300 dam3 STORAGE ALTERNATIVE
T.O.D. 964.6 ——— ——— ———
FSL. 961.5

SUMMARY OF DAMAGES

1) HIGHWAY NO. 529
3) BRIDGE TO BE ABANDONED
4) BRIDGE TO BE REPLACED
5) SINGLE PHASE POWER LINE TO BE RELOCATED
6) 3 PHASE POWER LINE TO BE RELOCATED
7) FARMSTEAD TO BE RELOCATED
8) AGT TELEPHONE LINE TO BE RELOCATED
9) HUTTERITE COLONY TO BE RELOCATED
10) TOWN OF VULCAN WATER INTAKE AND PUMPHOUSE TO BE RELOCATED



REV	DATE	REVISION DESCRIPTION	ENG	APPR

W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT
LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
SITE 7A FEASIBILITY DESIGN

86,300 dam^3 (70,000 ac ft.)
STORAGE ALT.
RESERVOIR COSTS
SUMMARY PLAN

DESIGNED P.B.	CHECKED	DATE 11·03·86	JOB No	DRAWING No D2
DRAFTED	APPROVED	SCALE NTS	SHEET No	